FAA - NO - 70 - 7

AD 710525

FINAL REPORT

CONTRACT FA68WA - 1900

NOISE EXPOSURE FORECAST CONTOURS FOR AIRCRAFT NOISE TRADEOFF STUDIES AT THREE MAJOR AIRPORTS

JULY 1970

Prepared For

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
OFFICE OF NOISE ABATEMENT

By

Dwight E. Bishop
Richard D. Horonjeff

BOLT BERANEK AND NEWMAN INC.
15808 Wyandotte Street
Van Nuys, California 91406

62

FINAL REPORT

FAA-NO-70-7

NOISE EXPOSURE FORECAST CONTOURS FOR AIRCRAFT NOISE TRADEOFF STUDIES AT THREE MAJOR AIRPORTS

JULY 1970

Prepared By

Dwight E. Bishop
Richard D. Horonjeff

This report has been approved for unlimited availability.

This report has been prepared for Bolt Beranek and Newman Inc., for the Office of Noise Abatement, Federal Aviation Administration, under Contract No. FA68WA-1900. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of the FAA. This report does not constitute a standard, specification or regulation.

BOLT BERANEK AND NEWMAN INC.
15808 Wyandotte Street
Van Nuys, California 91406

ABSTRACT

The relative effectiveness of three changes in aircraft operating procedures and/or aircraft hardware in reducing noise exposure around three major airports (O'Hare International Airport, Chicago, John F. Kennedy Airport, New York, and Los Angeles International Airport) were rated by determining the relative change in land areas falling within Noise Exposure Forecast (NEF) 30 and 40 contours. For projected 1975 operations, sets of NEF contours were calculated for changes which included: power cutbacks after takeoff and two segment approaches for all aircraft, and retrofit of current four-engine turbofan aircraft with either acoustically - lined nacelles or with a "quiet" engine under development by NASA. At all three airports, substantial reductions in land areas within NEF 30 and 40 contours occurred with retrofits and operational changes; relative area reductions ranged from 30.5% to 59.5%, with greatest reductions in both absolute and relative land areas observed at Chicago. For operational changes only sizeable reductions (10.5 to 25%) in land areas occurred at Chicago and Los Angeles, but only minor changes were observed for New York (a 5.5% reduction within the NEF 40 contour, and a 1.9% increase within the NEF 30 contour). The differences in effectiveness in reducing NEF contours between lined nacelle and "quiet" engine retrofits were quite moderate (land area differences of 1% to 10.9%), reflecting the increasing influence of noise from other aircraft on NEF values as four-engine turbofan aircraft noise levels are drastically reduced. A description of the digital computer program, methodology and evaluation and interpretations for NEF's can be found in the following reports prepared in performance of Contract FA68WA-1900: FAA-NO-69-2, FAA-NO-70-6, FAA-NO-70-8 and FAA-NO-70-9.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Con't)

LIST OF FIGURES (Con't)

I. INTRODUCTION

This report summarizes the results of the second and concluding part of an aircraft noise reduction tradeoff study conducted in performance of Tasks III and IV under Phase III of FAA Contract FA68WA-1900. The report presents Noise Exposure Forecast (NEF) contours for projected 1975 operations at three major airports - Los Angeles International Airport, O'Hare International Airport in Chicago, and J. F. Kennedy International Airport in New York.

Four sets of NEF contours are shown for each airport. One set shows the NEF contours for projected 1975 operations without introduction of special operational procedures or aircraft modifications for noise abatement purposes. The remaining three sets of contours represent the noise exposure for three sets of assumed changes in operational procedures or aircraft characteristics. The changes are as follows:

(1) Operational changes involving:

   a. Thrust cutback after takeoff, defined as a thrust cutback to a 6% climb gradient at a distance of 3.5 nautical miles from the start of takeoff roll (or a thrust cutback to a 6% climb gradient at a height of 1000 feet if the aircraft cannot reach 1000 feet prior to reaching 3.5 nautical miles from start of takeoff roll).

   b. A 6°/3° glide slope approach, defined as having the aircraft descend at a 6° glide angle until reaching 3 nautical miles from the runway threshold at which time the glide angle is changed to 3°.

(2) Aircraft modifications, combined with the operational changes of (1). The aircraft modifications consist of the retrofit of acoustically lined nacelles to four-engine turbofan aircraft Boeing 707, and Douglas DC-8 series.

(3) Aircraft modifications, combined with the operational changes of (1). The modifications consist of the retrofit of four-engine turbofan aircraft (707 and DC-8 series) with a "quiet" engine, currently under development by NASA.

The noise abatement changes studied were selected by the FAA, guided by the results of the initial tradeoff studies, reported in Ref. 1.* In the initial study, a relatively simple airport situation was assumed based upon a single runway with straight-out departure and approach flight paths.

---

* References are listed together at the end of the report.

In this report (as well as the initial tradeoff study), the relative effectiveness of the noise abatement procedures was rated by comparisons of the differences in land areas falling within the Noise Exposure Forecast 30 and 40 contours. These comparisons are discussed briefly in Section IV of this report. Section II of this report outlines the study approach and basic assumption employed in this study. Section III presents the NEF contours for the three airports. Appendix A presents a summary of the basic aircraft noise and takeoff profile information used for the "baseline" NEF contour development. Details of the methodology, assumptions, and expected accuracy of the NEF contours are given in Ref. 10.

II. STUDY APPROACH

A. Noise Exposure Forecast Computations and Interpretations

Noise Exposure Forecast (NEF) calculation procedures have been developed in the parallel studies of Refs. 2 and 3. The procedures in this report follow closely those of Ref. 2.* Basically, the NEF calculation provide estimates of the total noise environment arising from the multiple takeoff and landing operations of aircraft in the vicinity of an airport. The NEF values are calculated from: measures of the aircraft flyover noise described in terms of the effective perceived noise level (EPNL), expressed in EPNdB; and, the average number of flyovers per daytime and per nighttime periods. For convenience, the basic equations for calculating the NEF values at a ground position are given in Appendix B.

Interpretations of the NEF values in terms of expected influence on various land uses and expected community response are given in Reference 4. In this report, contours of NEF 30 and 40 values are given, which define the Noise Exposure Forecast areas used for tradeoff comparisons.

B. Aircraft Noise and Performance Characteristics

One of the major applications of the NEF procedures is in the comparison of the noise environment near an airport for current and projected future airport operations and in examining the effects of changes in modes of operations or aircraft mixes on land use. In these circumstances one must consider the total effect of number of operations of different types of aircraft. Since one is concerned in determining the total noise exposure resulting from the operation of a number of aircraft of varying characteristics, trip lengths, etc. precise descriptions of aircraft noise and aircraft performance may be replaced by generalized descriptors. Thus descriptions of aircraft noise in terms of EPNL vs. distance curves for classes of aircraft and generalized aircaft takeoff and landing profile will usually be adequate. The sets of generalized descriptors of aircraft noise and aircraft performance for the aircraft classes used in this study are given in Appendix A.**

---

* Currently Committee A-21 of the Society of Automotive Engineers is reviewing the NEF procedures of Refs. 2 and 3 for the purposes of recommending a common procedural use. For the purposes of the current study; differences in calculation procedures between those discussed in this report and those under consideration by the SAE are not likely to be large.

** The takeoff profile and noise data of Appendix A, because of refinements, differs slightly from those employed in the tradeoff study of Ref. 1.

Of the three changes considered in our study, two involve changes in the noise characteristics of current large four-engine turbofan aircraft (such as the Douglas DC8-50 and 60 series or the Boeing 707-320 B and C series aircraft). Figures 1 and 2 show the EPNL vs. distance characteristics assumed for these aircraft retrofitted with either lined nacelles or with the NASA quiet engine. The figures show these levels in comparison with the "baseline" EPNL curves from Appendix A.

In our initial tradeoff study, two degrees of effectiveness in the nacelle treatment was assumed. In the current study, only one set of values were assumed--that for maximum effectiveness. These estimates of nacelle treatment effectiveness were made prior to the availability of flight test data of aircraft outfitted with prototype acoustically treated nacelles. However, the values approximate quite well the preliminary experimental results reported in Ref. 5 as the comparison in the table below indicates.

Flight Condition	Current Study	Preliminary Results McDonnell-Douglas	Boeing
Takeoff Noise levels - 3.5 n. miles from start of takeoff roll			
- prior to power cutback	-5	-3.5*	-3.5*
- after power cutback	-8	-5*	-7*
Landing Noise 1 n. mile from runway threshold	-12	-10	-15.5

* At 300,000 lb gross weight.

All three changes studied involve aircraft operational changes: a thrust cutback after takeoff, and a two segment approach. These operational procedures are sketched in Fig. 3. The reductions in noise levels assumed to result from a power cutback after takeoff are listed in Table I. Table II lists the reduction in approach noise for a 6° glide slope relative to noise levels for a 3° glide slope.

C. Analysis Procedure

The Noise Exposure Forecast value at a particular ground point near an aircraft flyover path is dependent upon the noise levels produced by the different types of aircraft and the number of operations per day of each type of aircraft that generate these levels. The sizes and shapes of the NEF contours are therefore dependent upon the total number of flights per day and the proportion of aircraft types making up the total number of operations.

Information concerning the estimated volume of operations per major aircraft classification for 1975 has been provided by the Federal Aviation Administration. This information is summarized in Table III, IV and V for the three airports.

Similarly, identification of major flight paths and estimates of the percentage utilization of the major flight paths has also been provided by the FAA. The relative utilization of the major airport flight paths is summarized in Tables VI, VII and VIII; the flight paths are identified in Figs. 4, 5 and 6. Special profiles used for some segments of flight paths at John F. Kennedy Airport are listed in Fig. 7A and 7B.

In earlier studies, (Ref. 6, 7 and 8), Noise Exposure Forecast Contours were developed for projected 1975 operations at these same three airports. In general, the flight paths and relative utilization of the major flight paths assumed in the current study are the same as those of the earlier studies except at O'Hare International Airport where new runways and flight paths have been added, and runway utilization figures revised.

Comparisons of the projected 1975 number of operations from the airports with the earlier studies show that in general the total volume of operations now projected for 1975 is less than the earlier estimates. The changes reflect an updating of earlier estimates with allowance for the greater passenger-carrying capacity of many of the new aircraft expected to be in operation in 1975. In addition, the earlier study was based upon peak day estimates while the current projections (given in Table III, IV and V) are based on a "typical" day, an average of yearly estimates. As a consequence of this reduction in number of operations, the NEF contours for "baseline" operations presented in the next section will in general encompass significantly less area than the NEF contours developed earlier.

III. NEF CONTOURS

The Noise Exposure Forecast contours are given in Figs. 8, 9 and 10. Each figure comprises four sets of contours, -A, -B, -C and -D. Figures 8-A, 9-A and 10-A represent "baseline" operations for each of the three airports. The succeeding NEF contours for each figure show the NEF contours for the three noise abatement steps studied. The scale for the four contour sets of each figure has been held constant so that one may obtain an approximate indication of the change in size of NEF contours by comparing sets of contours for the same figure.

For each of the NEF contours presented in Figs. 8, 9 and 10, the land area in the NEF 30 and 40 contours has been computed. This data is tabulated in Table IX. To facilitate the comparison of relative area changes, the data of Table IX is restated in terms of percentages in Table X and in Fig. 11. In this table and figure, the baseline contour for each airport is taken as 100% for that airport, and the percentage of NEF areas for succeeding changes computed relative to the baseline area for that airport.

IV. NEF CONTOUR COMPARISONS

Comparisons of the relative land areas, considering only operational changes, show that sizeable reductions in land areas within NEF 30 and 40 contours were achieved at Chicago and Los Angeles (10.5 to 25%). However, at New York, a more moderate reduction in land areas within the NEF 30 contour (5.5%) was observed, together with a small <u>increase</u> (1.9%) in land area within the NEF 40 contour.

The differences between the results observed at Chicago and New York can be explained on the basis of the larger percentage of four-engine turbofan operations at New York (33.1% vs 21.6% at Chicago) and the larger percentage of long range flights occurring at New York. (At New York, 14.7% of the total take-offs consisted of four-engine turbofan aircraft departing on trip lengths of 1500 nautical miles or greater; at Chicago the percentage of similar flights was 6.1%). This same variation in effectiveness of operational changes with "mix" of aircraft was observed in the first phase of study; it results, of course, from the limited noise reduction available from a thrust cut-back for most current four-engine turbofan aircraft (see Table I). The difference in effectiveness of operational changes between New York and Los Angeles is not due to large differences in the proportions of aircraft classes but results from the much greater influence of approach noise at Los Angeles, compared to conditions at either New York or Chicago.

Introduction of equipment changes for four-engine turbofan aircraft results in major reductions in land areas within the NEF 30 and 40 contours at all three airports. With retrofit of either lined nacelles or "quiet" engines, the greatest absolute and relative reductions in land areas within contours occurs at Chicago. The reductions in land areas are somewhat smaller for Los Angeles and New York, but are still substantial, with the reductions ranging from 57 to 69.5% of the original land areas.

With lined nacelle retrofits, land areas within NEF 30 and 40 contours were reduced to 47 to 69.5% of original areas. As might be expected because of the lower noise levels, retrofit with the "quiet" engine resulted in even greater reduction in land areas, to 40.5 to 68.5% of original areas. However, the differences in relative land areas within NEF 30 and 40 contours between lined nacelle and "quiet" engine retrofit were quite moderate, ranging from 1% (NEF 30 and 40 contours at Los Angeles) to 10.9% (NEF 30 at New York). This moderate reduction in land areas within NEF 30 and 40 contours reflects the increasing

influence on NEF values of the noise produced by other unmodified aircraft, as the four-engine turbofan aircraft noise output is reduced beyond that achieved with the lined nacelles.

Comparison of relative areas with retrofit with the results of the Reference 1 study shows that while trends are generally consistent, the relative reductions in land areas at the three major airports are generally less than might be anticipated on the basis of the earlier study. A major reason for this difference lies in the differences in proportion of aircraft assumed for retrofit. For the two aircraft mixes assumed in the earlier study, retrofit percentages were 35% and 60%, while in the current study, using the revised 1975 forecast data, retrofit aircraft account for 21.6% of total operations at Chicago and 33.1% at Los Angeles and New York.

REFERENCES

1. D. E. Bishop, R. D. Horonjeff, "Noise Exposure Forecast Contour Interpretations of Aircraft Noise Tradeoff Studies," FAA NO-69-2, May 1969.

2. D. E. Bishop, R. D. Horonjeff, "Procedures for Developing Noise Exposure Forecast Areas for Aircraft Flight Operations," FAA DS-67-10, August 1967.

3. SAE Research Committee R2.5 "Technique for Developing Noise Exposure Forecasts," FAA DS-67-14, August 1967.

4. W. J. Galloway, D. E. Bishop, "Noise Exposure Forecasts: Evolution, Evaluation, Extensions, and Land Use Interpretations," FAA NO-70-9, 1970.

5. NASA SP-220, "NASA Acoustically Treated Nacelle Program," October 15, 1969.

6. D. E. Bishop, R. D. Horonjeff, "1965, 1970 and 1975 Noise Exposure Forecast Areas for John F. Kennedy Airport, New York," FAA DS-67-11, August 1967.

7. D. E. Bishop, R. D. Horonjeff, "1965, 1970 and 1975 Noise Exposure Forecast Areas for Chicago O'Hare International Airport," FAA DS-67-12, August 1967.

8. D. E. Bishop, R. D. Horonjeff, "1965, 1970 and 1975 Noise Exposure Forecast Areas for Los Angeles International Airport," FAA DS-67-13, August 1967.

9. R. D. Horonjeff, A. Paul "A Digital Computer Program for Computation of Noise Exposure Forecast Contours," FAA NO-70-6, June 1970.

10. D. E. Bishop, M. A. Simpson, "Noise Exposure Forecast Contours for 1967, 1970 and 1975 Operations at Selected Airports," FAA NO-70-8, 1970.

11. W. C. Sperry, "Aircraft Noise Evaluation," FAA NO-68-34, September 1968.

TABLE I

ASSUMED REDUCTIONS IN TAKEOFF NOISE LEVELS FOR SIX PERCENT CLIMB GRADIENT AND FOR LEVEL FLIGHT DUE TO THRUST CUTBACK

Aircraft Classification	Flight Condition	Noise Reduction* in EPNdB Trip Length in Nautical Miles 0-500	500-1000	1000-1500	1500-2500	2500-3500	3500-4500	4500+
4-Engine Turbojet	6% Climb	6	6	6	5	4	3	3
	Level Flight	8	8	8	7	6	5	5
4-Engine Turbofan Unmodified	6% Climb	1	1	1	1	1	1	1
	Level Flight	3	3	3	3	3	3	3
Lined Nacelles	6% Climb	3	3	3	3	3	3	3
	Level Flight	5	5	5	5	5	5	5
"Quiet"Engine	6% Climb	4	4	4	4	4	4	4
	Level Flight	6	6	6	6	6	6	6
3-Engine Turbofan	6% Climb	7	6	6	5	5	5	5
	Level Flight	9	8	8	7	7	7	7
3-Engine Turbofan (stretched)	6% Climb	6	5	4	4	4	4	4
	Level Flight	8	7	6	6	6	6	6
2-Engine Turbofan	6% Climb	6	6	6	6	6	6	6
	Level Flight	8	8	8	8	8	8	8
"New Technology" 4-Engine Turbofan (Jumbo)	6% Climb	6	6	6	6	5	4	3
	Level Flight	8	8	8	8	7	6	5
"New Technology" 3-Engine Turbofan (Air Bus)	6% Climb	7	6	6	5	5	5	5
	Level Flight	9	8	8	7	7	7	7
U.S. SST	6% Climb	12	12	12	12	12	10	10
	Level Flight	14	14	14	14	14	12	12

* Reduction From Takeoff Noise Levels

TABLE II

REDUCTION IN APPROACH NOISE LEVELS FOR 6° GLIDE SEGMENT*

Aircraft Classification	Noise Reduction* in EPNdB
4-Engine Turbojet	3
4-Engine Turbofan	
- Unmodified	1
- Lined nacelles	3
- "Quiet" engine	4
2- and 3-Engine Turbofan	3
"New Technology" 4-Engine Turbofan	3
"New Technology" 3-Engine Turbofan	3
U.S. SST	3

* These reductions apply to the EPNL values assumed for a conventional (3°) glide slope, and are assumed constant over the approach profile segment E - F of Fig. 3.

TABLE III

PROJECTED NUMBER OF AIRCRAFT OPERATIONS PER DAY
IN 1975 - O'HARE INTERNATIONAL AIRPORT

Aircraft Classification	Day/ Night	Landings	Takeoffs — Trip Length in Nautical Miles						
			0-500	500-1000	1000-1500	1500-2500	2500-3500	3500-4500	4500+
4-Engine Turbojet	D	53.699	36.986	3.425	9.589	3.699	0.0	0.0	0.0
	N	15.616	9.315	0.685	4.110	1.507	0.0	0.0	0.0
4-Engine Turbofan (standard)	D	123.836	35.616	43.836	16.438	22.603	1.096	4.247	0.0
	N	37.808	11.781	10.959	4.110	10.959	0.0	0.0	0.0
4-Engine Turbofan (stretched)	D	39.726	4.110	17.808	2.740	13.562	0.0	1.507	0.0
	N	9.589	0.411	2.740	0.959	5.205	0.0	0.274	0.0
3-Engine Turbofan (standard)	D	165.411	157.534	7.877	0.0	0.0	0.0	0.0	0.0
	N	23.082	21.918	1.164	0.0	0.0	0.0	0.0	0.0
3-Engine Turbofan (stretched)	D	145.205	49.315	95.890	0.0	0.0	0.0	0.0	0.0
	N	21.370	7.671	13.699	0.0	0.0	0.0	0.0	0.0
2-Engine Turbofan	D	165.411	157.534	7.877	0.0	0.0	0.0	0.0	0.0
	N	23.082	21.918	1.164	0.0	0.0	0.0	0.0	0.0
"New Technology" 4-Engine Turbofan	D	48.630	4.[illegible]95	20.959	0.0	20.548	0.0	2.329	0.0
	N	11.644	0.085	3.425	0.0	6.849	0.0	0.685	0.0
"New Technology" 3-Engine Turbofan	D	76.712	12.329	30.137	6.849	27.397	0.0	0.0	0.0
	N	15.616	1.918	4.110	2.740	6.849	0.0	0.0	0.0

TABLE IV

PROJECTED NUMBER OF AIRCRAFT OPERATIONS PER DAY
IN 1975 - LOS ANGELES INTERNATIONAL AIRPORT

Aircraft Classification	Day/ Night	Landings	Takeoffs						
			Trip Length in Nautical Miles						
			0- 500	500- 1000	1000- 1500	1500- 2500	2500- 3500	3500- 4500	4500+
4-Engine Turbojet	D	26.575	5.479	4.110	5.479	9.589	1.918	0.0	0.0
	N	6.164	0.685	1.370	1.370	2.740	0.0	0.0	0.0
4-Engine Turbofan (standard)	D	157.534	57.534	24.658	35.616	33.425	4.932	1.370	0.0
	N	28.082	13.699	2.740	5.479	4.795	0.685	0.685	0.0
4-Engine Turbofan (stretched)	D	21.233	2.740	0.0	0.0	11.781	4.110	0.0	2.603
	N	5.479	1.096	0.0	0.0	4.384	0.0	0.0	0.0
3-Engine Turbofan (standard)	D	80.616	72.740	4.110	3.767	0.0	0.0	0.0	0.0
	N	9.795	8.219	1.301	0.274	0.0	0.0	0.0	0.0
3-Engine Turbofan (stretched)	D	56.575	51.781	4.795	0.0	0.0	0.0	0.0	0.0
	N	8.904	8.219	0.685	0.0	0.0	0.0	0.0	0.0
2-Engine Turbofan	D	80.616	72.740	4.110	3.767	0.0	0.0	0.0	0.0
	N	9.795	8.219	1.301	0.274	0.0	0.0	0.0	0.0
"New Technology" 4-Engine Turbofan	D	60.822	3.973	0.0	0.0	45.890	10.959	0.0	0.0
	N	15.068	0.685	0.0	0.0	13.014	1.370	0.0	0.0
"New Technology" 3-Engine Turbofan	D	55.890	21.644	0.0	0.0	34.247	0.0	0.0	0.0
	N	9.589	2.740	0.0	0.0	6.849	0.0	0.0	0.0
U.S. SST	D	8.767	0.0	2.740	0.0	0.0	6.027	0.0	0.0
	N	0.685	0.0	0.0	0.0	0.0	0.685	0.0	0.0

TABLE V

PROJECTED NUMBER OF AIRCRAFT OPERATIONS PER DAY
IN 1975 - JOHN F. KENNEDY INTERNATIONAL AIRPORT

Aircraft Classification	Day/Night	Landings	Takeoffs: Trip Length in Nautical Miles 0-500	500-1000	1000-1500	1500-2500	2500-3500	3500-4500	4500+
4-Engine Turbojet	D	33.973	19.178	2.466	2.329	10.000	0.0	0.0	0.0
	N	7.945	5.890	0.274	0.411	1.370	0.0	0.0	0.0
4-Engine Turbofan (standard)	D	143.014	6.849	42.603	23.767	26.986	12.329	23.973	1.507
	N	24.384	1.507	9.589	5.479	4.932	2.055	0.822	0.0
4-Engine Turbofan (stretched)	D	30.822	8.219	1.370	5.479	4.110	4.110	7.534	0.0
	N	4.932	1.507	0.0	1.370	0.0	1.370	0.685	0.0
3-Engine Turbofan (standard)	D	58.630	54.110	2.329	2.192	0.0	0.0	0.0	0.0
	N	8.767	7.877	0.342	0.548	0.0	0.0	0.0	0.0
3-Engine Turbofan (stretched)	D	64.521	23.973	27.397	13.151	0.0	0.0	0.0	0.0
	N	10.137	3.425	3.425	3.288	0.0	0.0	0.0	0.0
2-Engine Turbofan	D	58.630	54.110	2.329	2.192	0.0	0.0	0.0	0.0
	N	8.767	7.877	0.342	0.548	0.0	0.0	0.0	0.0
"New Technology" 4-Engine Turbofan	D	76.164	0.0	13.699	10.274	19.863	18.630	10.959	2.740
	N	10.959	0.0	0.0	1.370	3.425	4.110	2.055	0.0
"New Technology" 3-Engine Turbofan	D	44.521	12.329	10.959	6.849	10.274	4.110	0.0	0.0
	N	9.863	1.370	2.740	2.329	2.055	1.370	0.0	0.0
U.S. SST	D	16.438	0.0	0.0	0.0	0.0	8.904	7.534	0.0
	N	1.781	0.0	0.0	0.0	0.0	1.370	0.411	0.0

TABLE VI

FLIGHT PATH UTILIZATION PERCENTAGES
FOR O'HARE INTERNATIONAL AIRPORT

Flight Path	T/O	L	Flight Path	T/O	L
32L-A	8.0	15.4	9L-D	6.4	-
32L-B	1.3	15.4	9L-E	5.4	-
32L-C	4.0	-	9R-A	8.8	2.2
32L-D	2.6	-	9R-B	3.7	-
32L-E	-	15.4	9R-C	5.0	2.2
32R-A	24.6	5.0	27L-A	13.2	5.8
32R-B	24.6	-	27L-B	9.8	-
32R-C	12.3	-	27L-C	5.5	-
32R-D	12.3	-	27L-D	4.2	-
32R-E	-	5.0	27L-E	-	5.8
14L-A	5.3	13.6	27L-F	3.4	-
14L-B	3.9	-	27R-A	2.6	13.8
14L-C	2.0	-	27R-B	1.1	-
14L-D	2.0	-	27R-C	1.1	13.8
14L-E	1.4	13.6	4R-A	0.8	5.0
14R-A	6.4	13.7	4R-B	1.2	-
14R-B	5.0	-	4R-C	-	5.0
14R-C	2.5	-	4R-D	0.8	-
14R-D	2.5	-	4L-A	1.1	5.0
14R-E	1.4	13.7	4L-B	0.6	5.0
14R-F	0.4	10.0	4L-C	0.5	0.0
14R-G	1.0	3.7	22L-A	10.0	10.0
14R-H	1.0	-	22L-B	5.7	-
14R-I	-	3.7	22L-C	4.3	-
9L-A	15.3	1.2	22L-D	-	10.0
9L-B	-	1.2	22R-A	0.3	8.7
9L-C	8.7	-	22R-B	0.2	0.0
			22R-C	0.0	8.7

TABLE VII

FLIGHT PATH UTILIZATION PERCENTAGES
FOR LOS ANGELES INTERNATIONAL AIRPORT

Flight Path	T/O	L	Flight Path	T/O	L
24R-A	10.0	0.2	6-F	-	15.3
24L-A	22.0	0.3	6-7-A	-	3.9
25R-A	51.0	0.5	7R-A	0.5	43.0
25L-A	15.0	1.0	7L-A	1.0	23.0
6R-A	0.2	22.0	7-A	-	11.5
6L-A	0.3	10.0	7-B	-	54.5
6-A	0.5	32.0	7-C	-	52.0
6-B	-	6.1	7-D	-	17.3
6-C	-	24.5	7-E	-	34.7
6-D	-	1.4	7-F	-	28.8
6-E	-	9.2	7-G	-	5.9

TABLE VIII

FLIGHT PATH UTILIZATION PERCENTAGES FOR
JOHN F. KENNEDY INTERNATIONAL AIRPORT

Flight Path	T/O	L	Flight Path	T/O	L
4R-A	0.3	17.5	13R-D	7.7	-
4R-B	0.3	-	13R-E	7.7	-
4R-C	0.1	-	13L-A	-	38.0
4R-D	0.2	-	22R-A	15.5	-
4R-E	-	17.5	22L-A	-	26.3
13R-A	23.1	-	31R-A	-	18.2
13R-B	15.4	-	31L-A	61.1	-
13R-C	7.7	-	31L-B	25.5	-

TABLE IX

LAND AREAS WITHIN NEF 30 AND NEF 40 CONTOURS

Condition	Land Areas in Sq. Mi.					
	O'Hare Chicago		Los Angeles International		J. F. Kennedy New York	
	NEF 30+	NEF 40+	NEF 30+	NEF 40+	NEF 30+	NEF 40+
Baseline	103.6	23.7	33.3	14.4	53.3	14.6
Operational Changes Only	81.6	21.2	25.0	12.9	54.3	13.8
Lined Nacelle Retrofit*	48.5	15.1	19.3	10.0	36.6	9.4
"Quiet" Engine Retrofit*	42.0	13.6	18.9	9.9	30.8	8.4

* Includes operational changes for all aircraft, and equipment changes only for four-engine turbofan aircraft (DC-8, 707 types).

TABLE X

PERCENTAGE OF LAND AREAS WITHIN NEF 30 AND NEF 40 CONTOURS

Condition	O'Hare Chicago		Los Angeles International		J. F. Kennedy New York	
	NEF 30+	NEF 40+	NEF 30+	NEF 40+	NEF 30+	NEF 40+
Baseline	100	100	100	100	100	100
Operational Changes Only	78.5	89.5	75.0	89.5	101.9	94.5
Lined Nacelle Retrofit*	47.0	63.5	58.0	69.5	68.7	64.1
"Quiet" Engine Retrofit*	40.5	57.5	57.0	68.5	57.8	57.6

* Includes operational changes for all aircraft, and equipment changes only for four-engine turbofan aircraft (DC-8, 707 types).

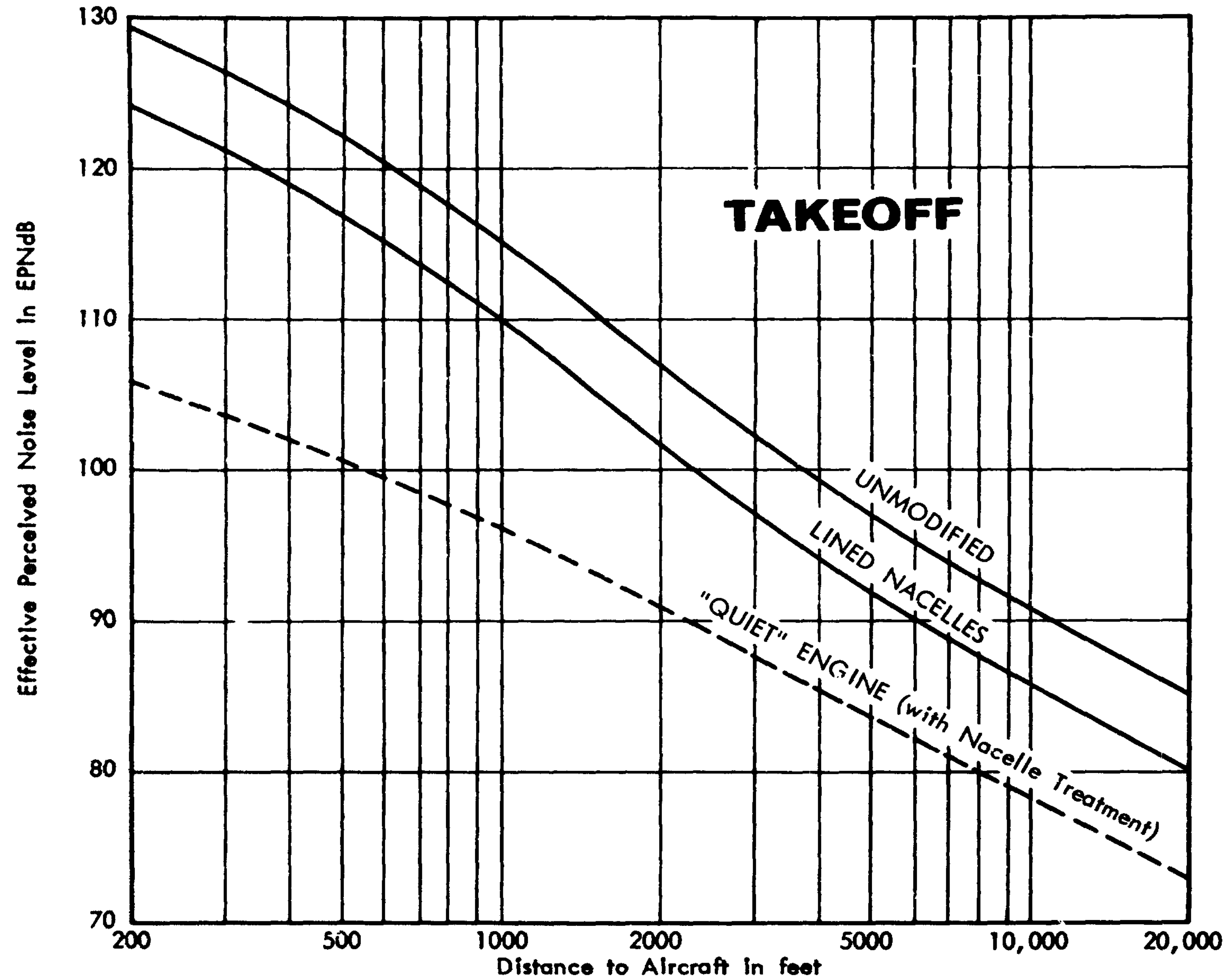


FIGURE 1. EFFECTIVE PERCEIVED NOISE LEVELS - TAKEOFFS OF LARGE FOUR ENGINE TURBOFAN AIRCRAFT WITH RETROFITS

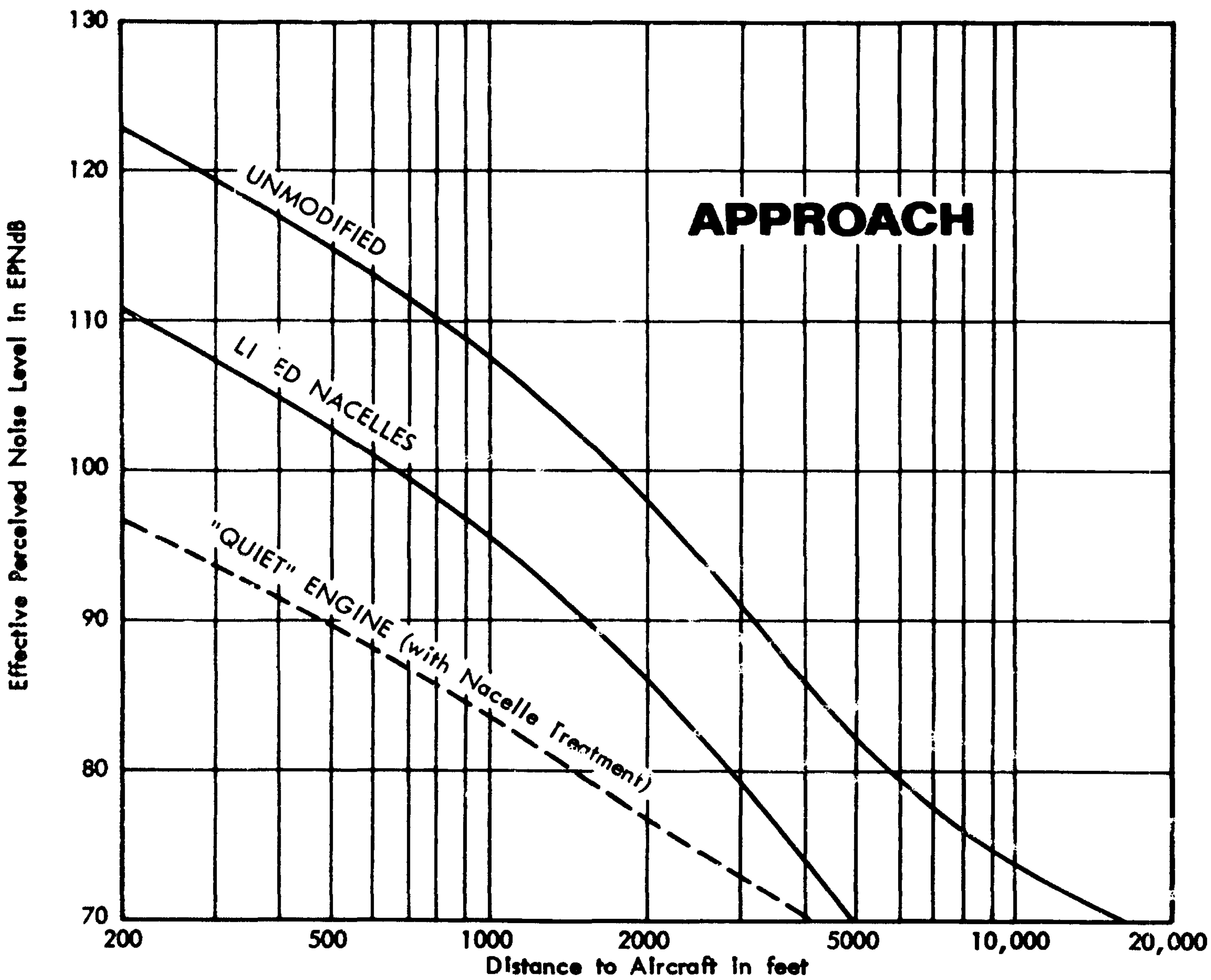
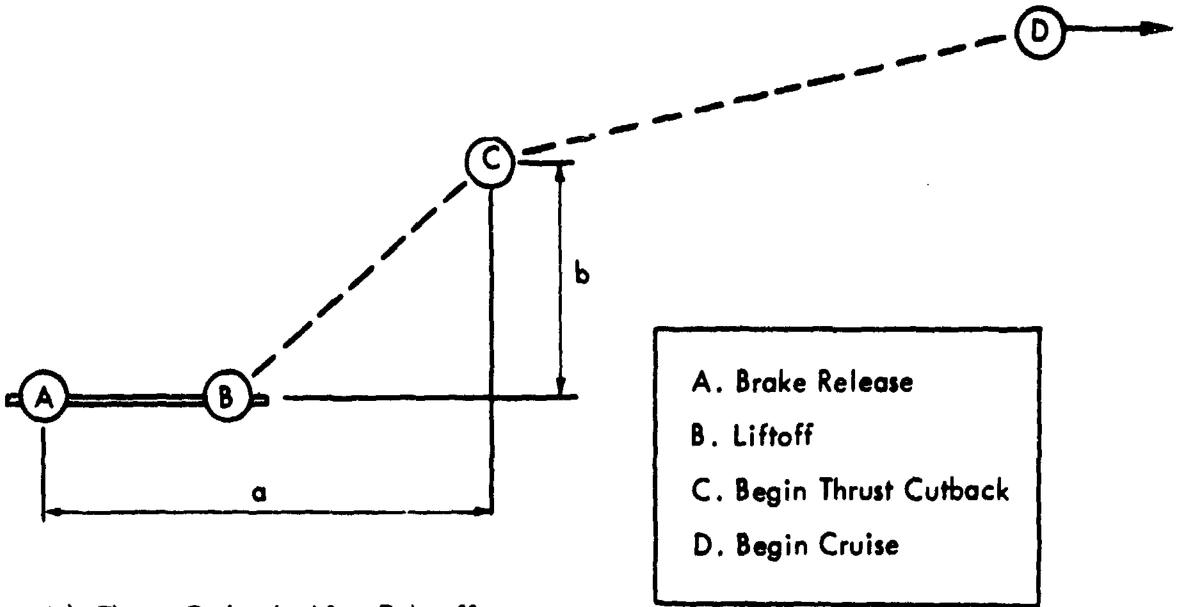
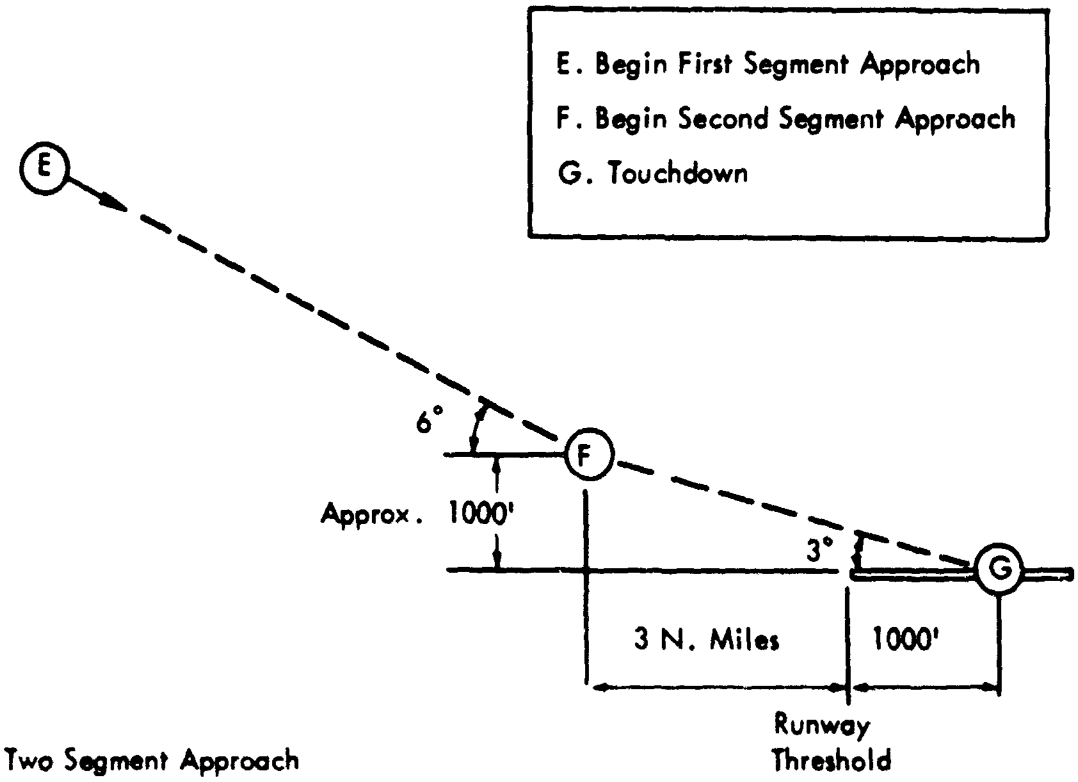


FIGURE 2. EFFECTIVE PERCEIVED NOISE LEVELS - LANDINGS OF LARGE FOUR ENGINE TURBOFAN AIRCRAFT WITH RETROFITS



(a) Thrust Cutback After Takeoff



(b) Two Segment Approach

FIGURE 3. AIRCRAFT FLIGHT PROFILE MODIFICATIONS

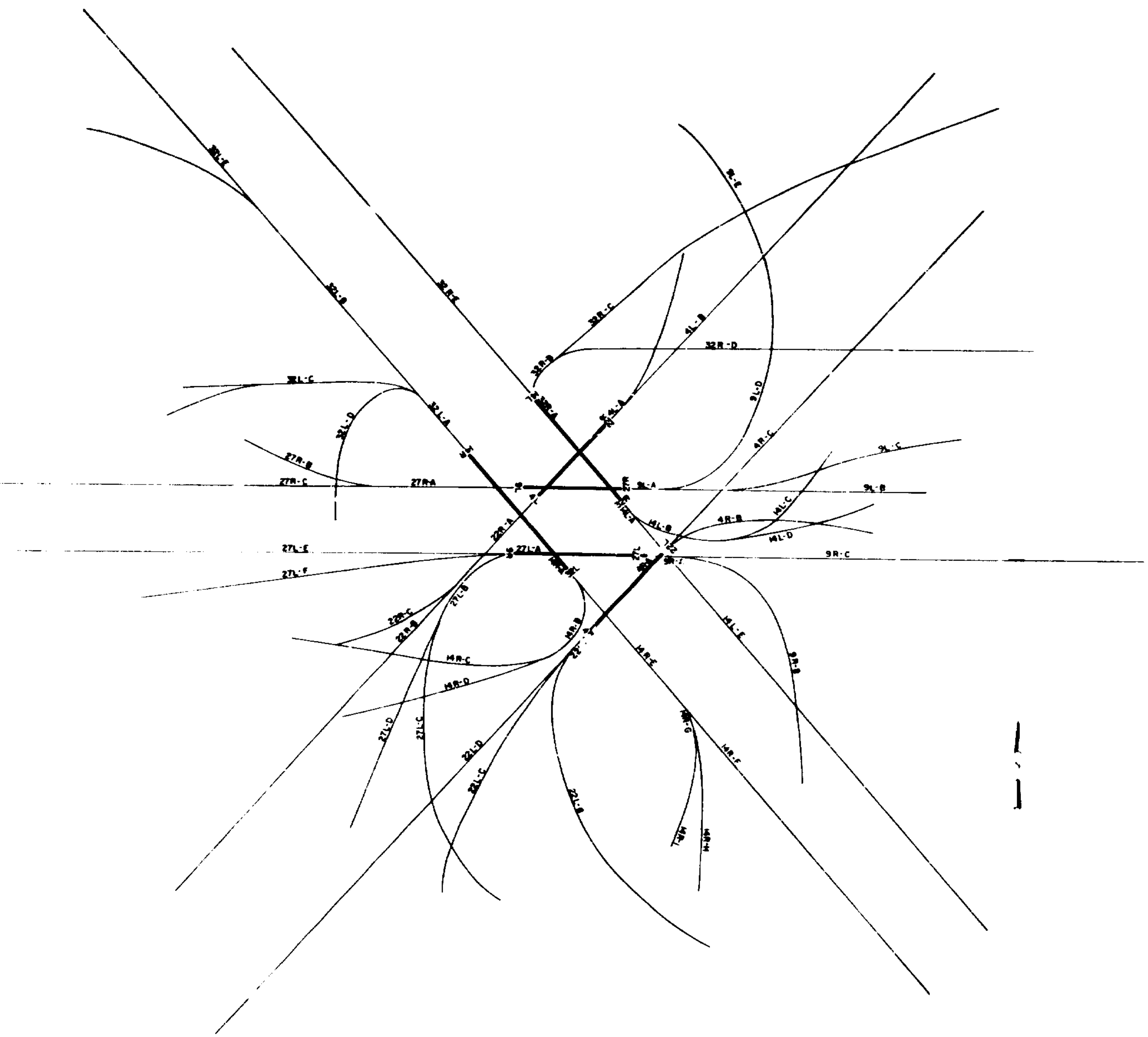


FIGURE 4. MAJOR FLIGHT PATHS FOR O'HARE INTERNATIONAL AIRPORT, CHICAGO

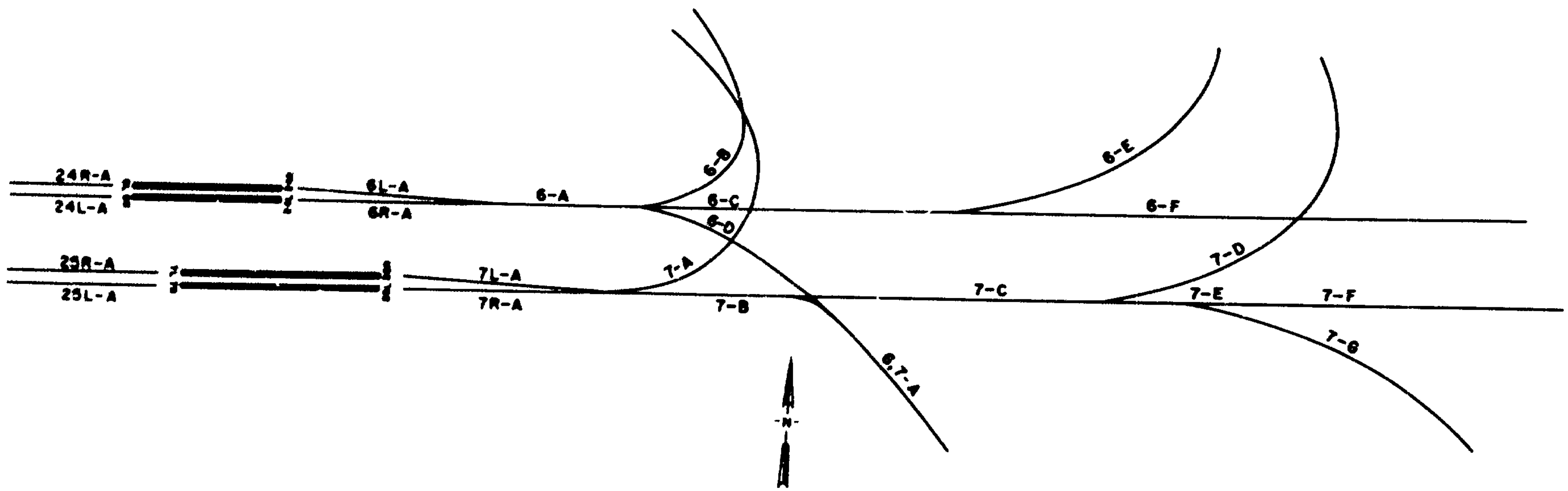


FIGURE 5. MAJOR FLIGHT PATHS FOR LOS ANGELES INTERNATIONAL AIRPORT

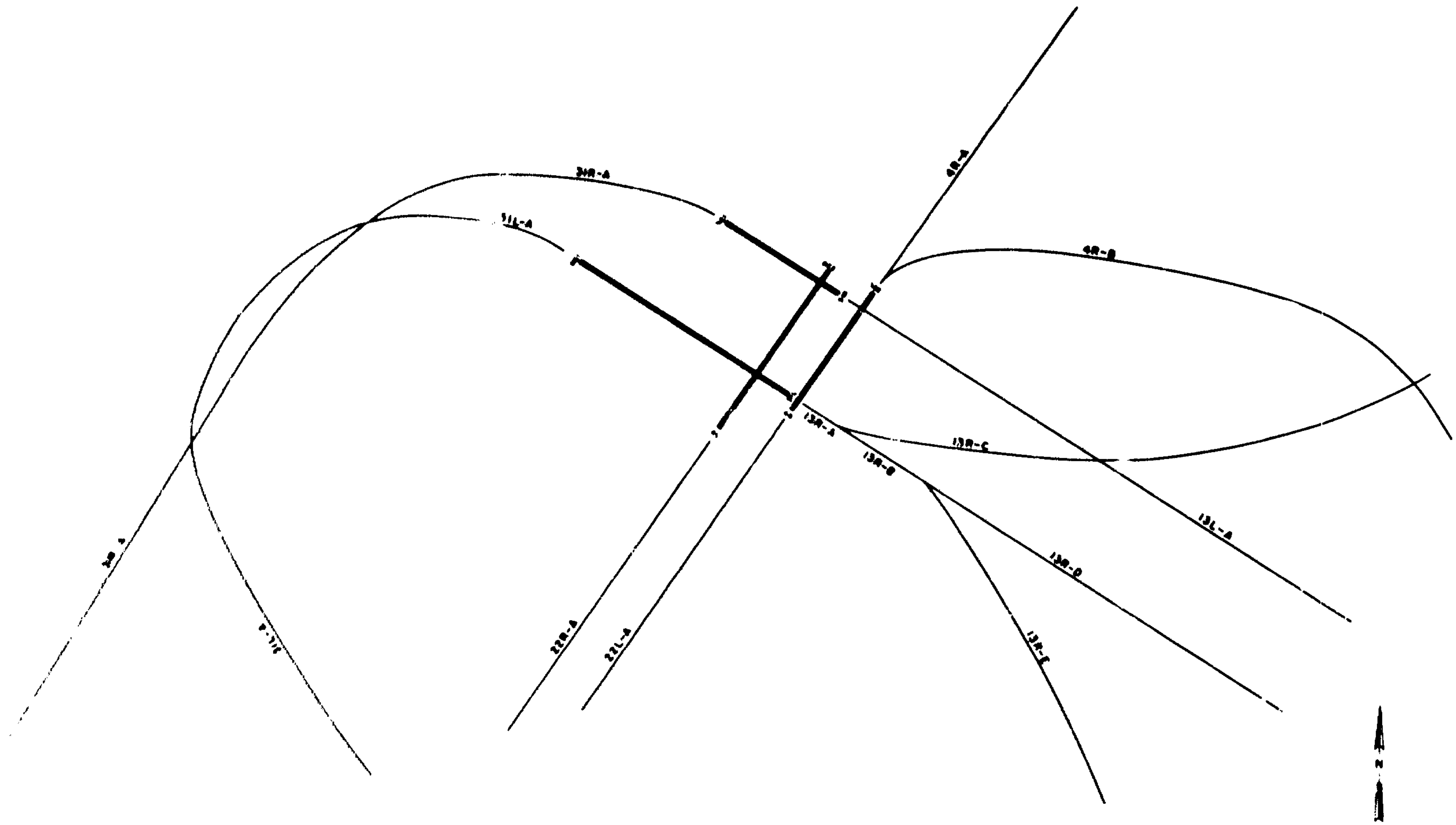
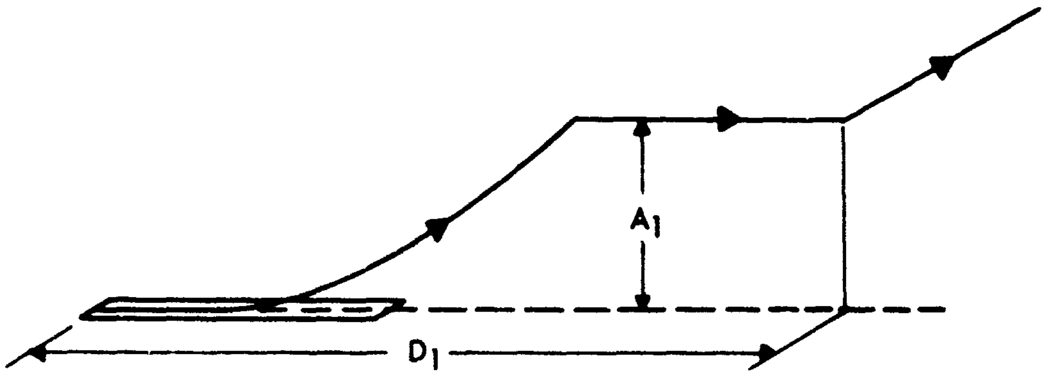


FIGURE 6. MAJOR FLIGHT PATHS FOR JOHN F. KENNEDY INTERNATIONAL AIRPORT, NEW YORK

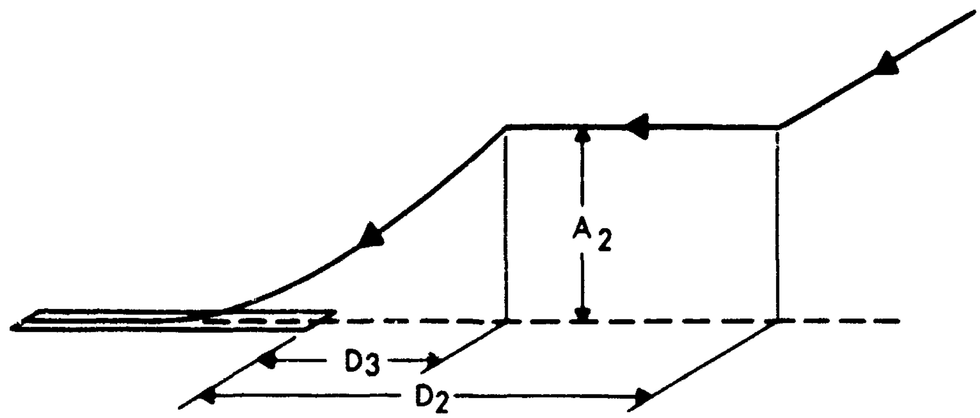


FLIGHT PATH	MAXIMUM ALTITUDE RESTRICTION, A_1	DISTANCE TO TERMINATION OF ALTITUDE RESTRICTION, D_1
4R-A	4000 Feet	17.3 Naut Miles
4R-B	4000	17.3
4R-C	4000	7.9
4R-D	4000	17.3
13R-A	4000	17.3
13R-B	4000	17.3
13R-C	4000	10.4
13R-D	4000	17.3
13R-E	4000	17.3
22R-A	4000	17.3
31L-A	2500/4000 (Note 2)	12.5/23.1
31L-B	2500/4000	12.5/23.1

Notes

1. See Figure 6.
2. 50% of aircraft restricted to 2500' until 12.5 Naut Miles
   50% of aircraft restricted to 4000' until 23.1 Naut Miles
   due to operations at LGA

FIGURE 7A. ALTITUDE RESTRICTIONS FOR TAKEOFFS FROM J.F. KENNEDY INTERNATIONAL AIRPORT



FLIGHT PATH	ALTITUDE TO BE MAINTAINED, A_2	DISTANCE FROM R/W THRESHOLD FROM D_2	TO D_3
4R-A	3000 Feet	∞	19.9 Naut Miles
	2500	18.4 Naut Miles	13.2
4R-E	3000	∞	19.9
	2500	18.4	13.2
13L-A	3000	∞	18.4
	2000	15.7	6.28
22L-A	2500/1000	∞	7.8/3.1
31R-A	2000/1500 (Note 2)	9.9	5.8

Notes

1. See Figure 6
2. 2000' to be maintained until 9.9 naut miles from threshold, then decend to 1500' at 5.8 naut miles from threshold (intercept glide slope at this point).

FIGURE 7B. SPECIAL LANDING PROFILES FOR J.F. KENNEDY INTERNATIONAL AIRPORT

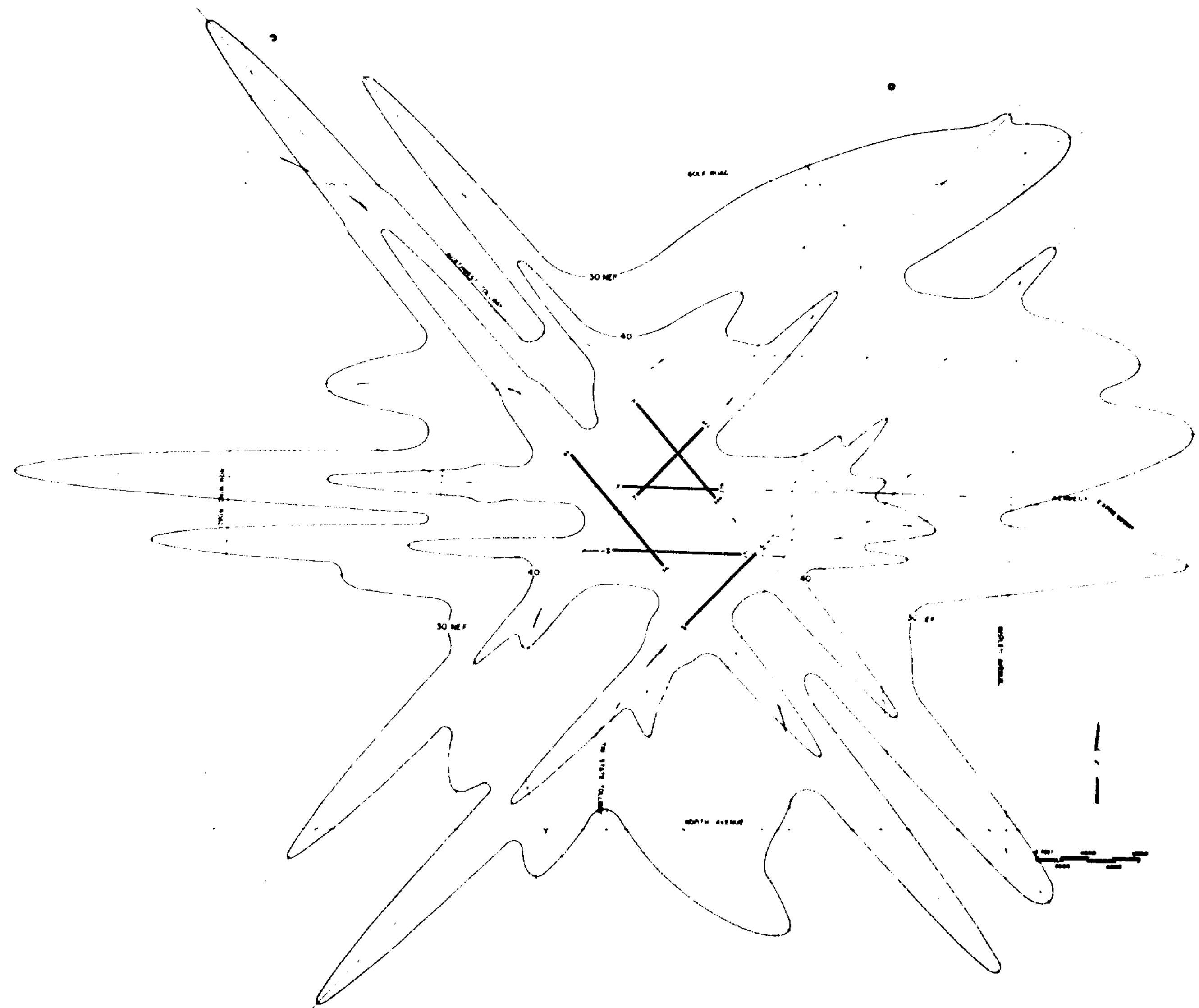


FIGURE 8-A. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT O'HARE INTERNATIONAL AIRPORT, CHICAGO - "BASELINE" CONDITIONS WITH NO SPECIAL NOISE ABATEMENT CHANGES

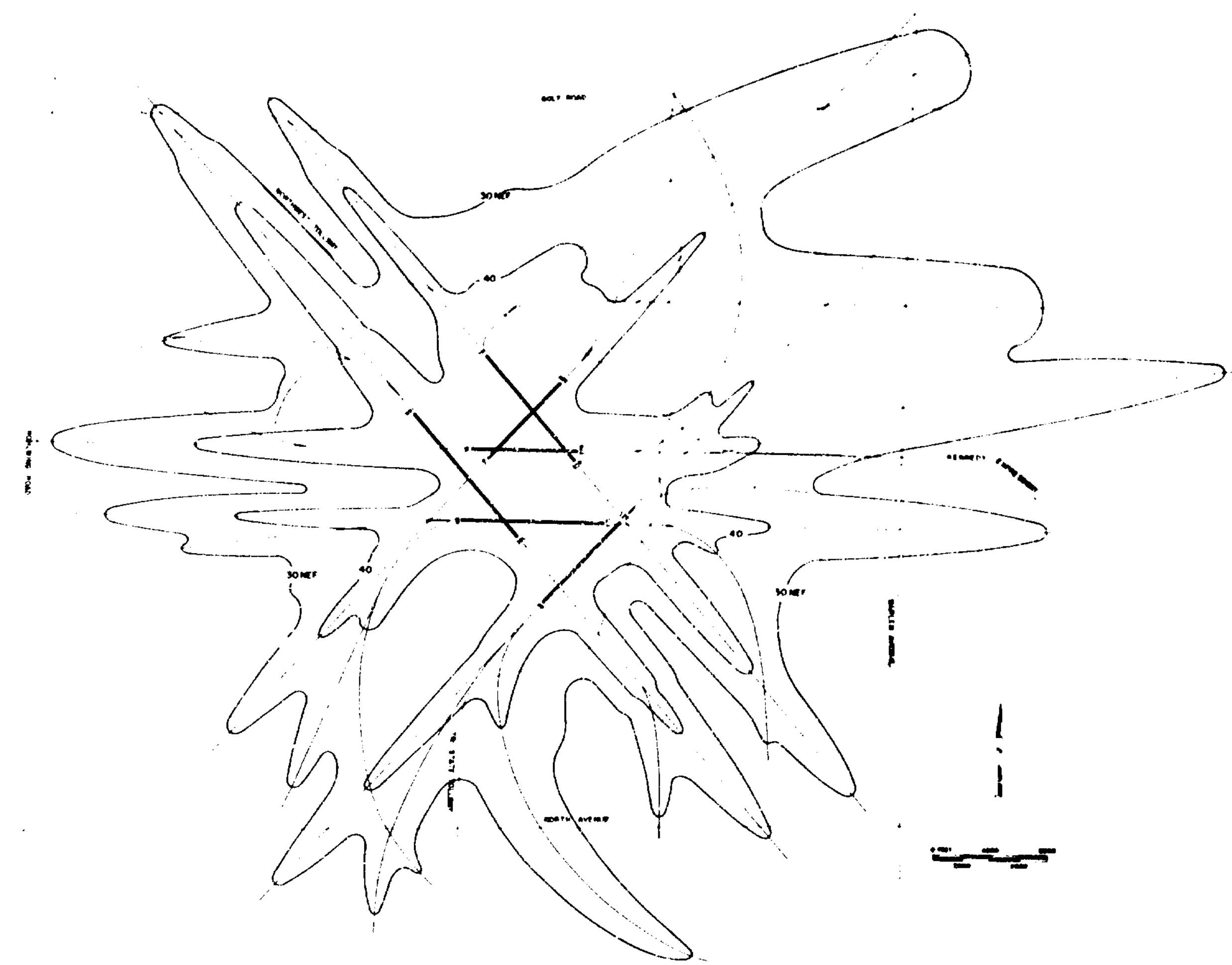


FIGURE 8-B. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT O'HARE INTERNATIONAL AIRPORT, CHICAGO - OPERATIONAL CHANGES ONLY (THRUST CUTBACK AFTER TAKEOFF AND TWO SEGMENT APPROACH)

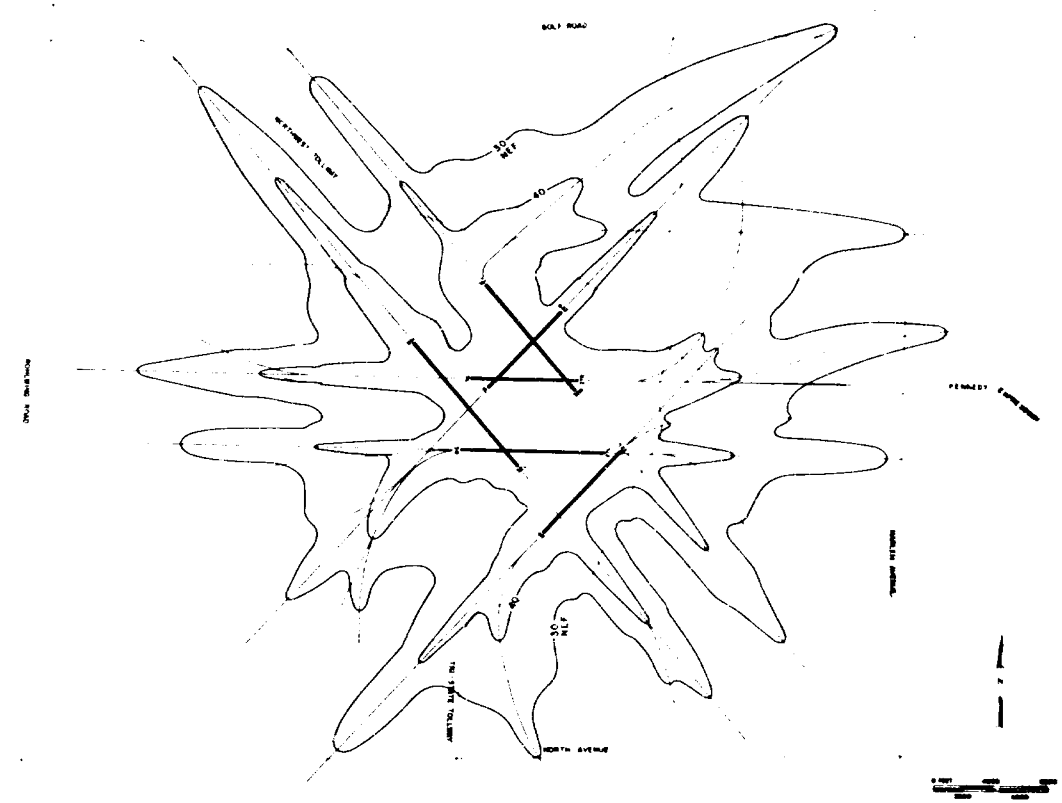


FIGURE 8-C. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT O'HARE INTERNATIONAL AIRPORT, CHICAGO - OPERATIONAL CHANGES AND RETROFIT OF FOUR ENGINE TURBOFAN AIRCRAFT WITH LINED NACELLES

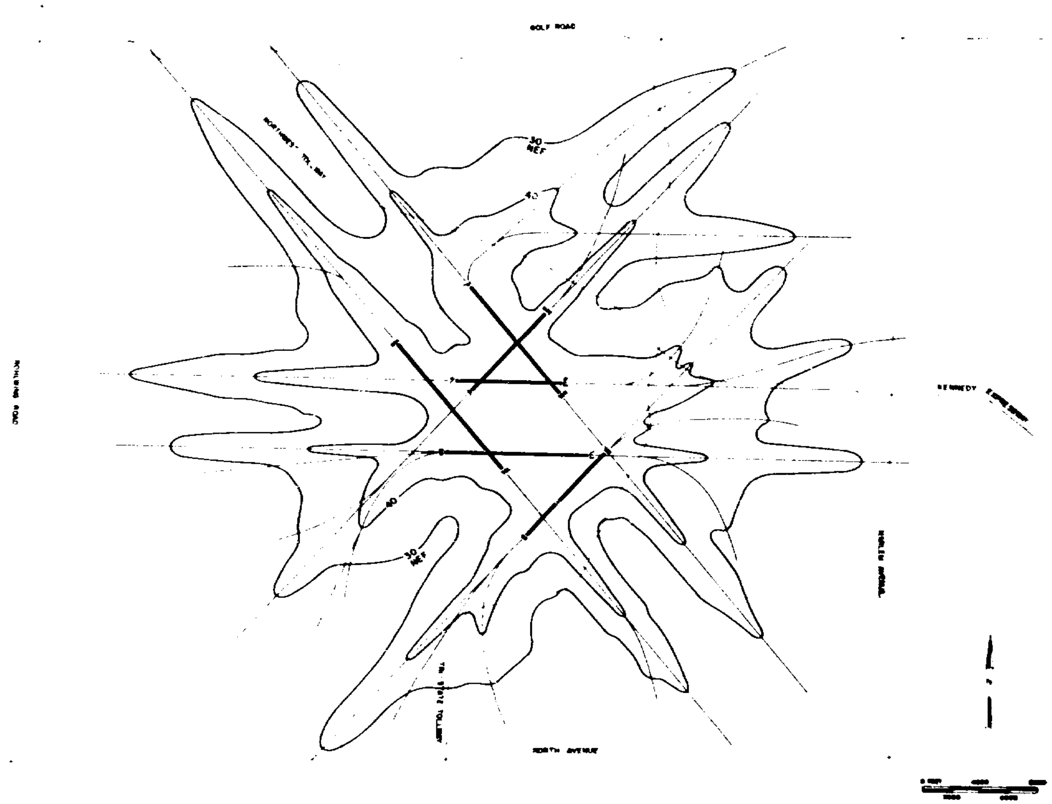


FIGURE 8-D. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT O'HARE INTERNATIONAL AIRPORT, CHICAGO - OPERATIONAL CHANGES AND RETROFIT OF FOUR ENGINE TURBOFAN AIRCRAFT WITH A "QUIET ENGINE"

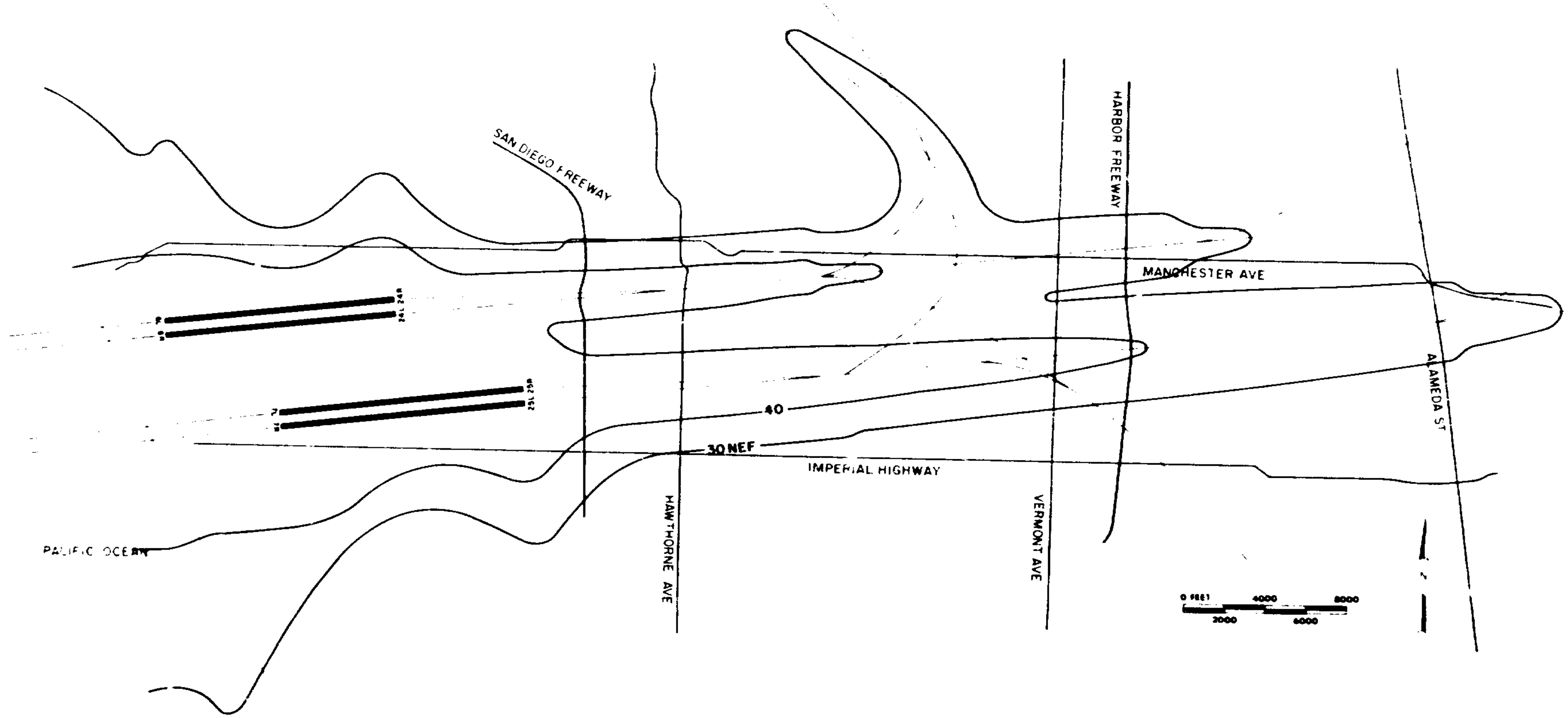


FIGURE 9-A. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT LOS ANGELES INTERNATIONAL AIRPORT - "BASELINE" CONDITIONS WITH NO SPECIAL NOISE ABATEMENT CHANGES

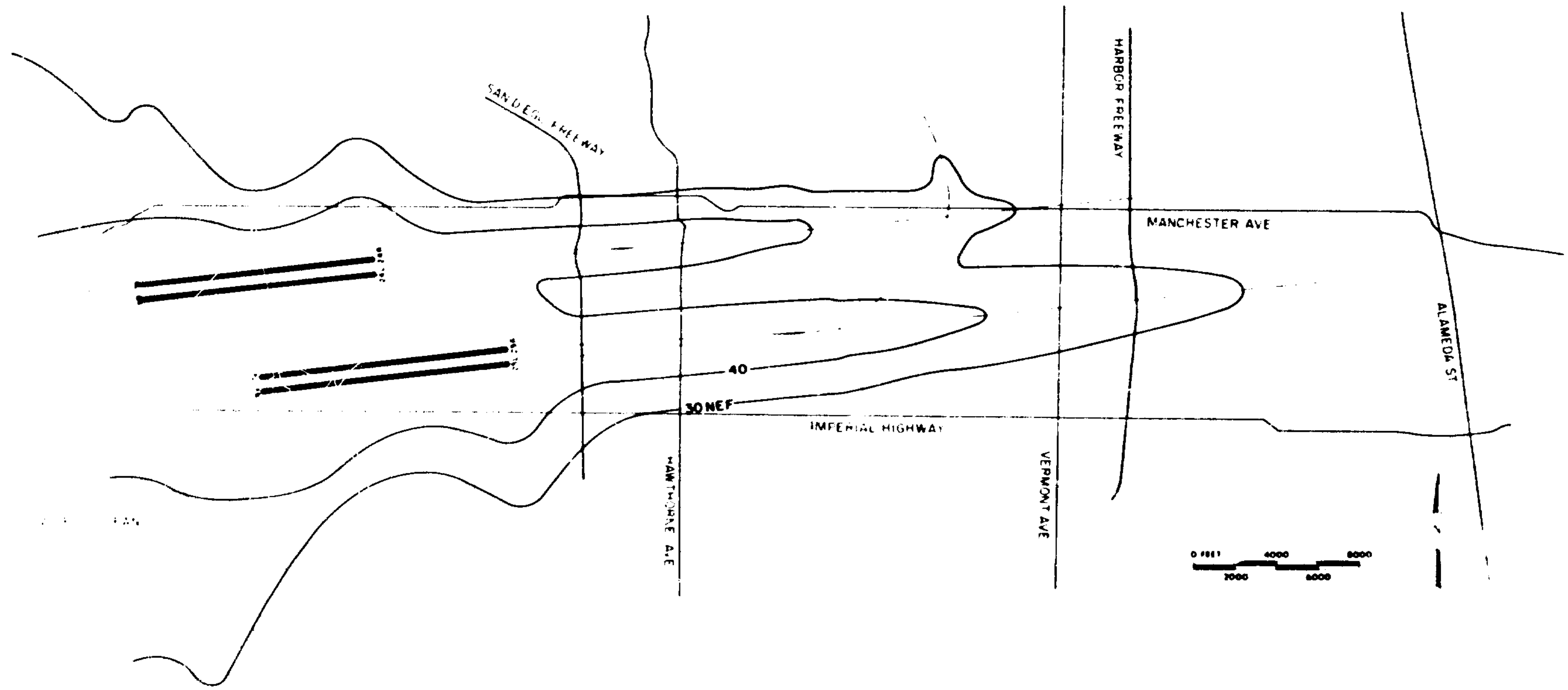


FIGURE 9-B. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT LOS ANGELES INTERNATIONAL AIRPORT - OPERATIONAL CHANGES ONLY (THRUST CUTBACK AFTER TAKEOFF AND TWO SEGMENT APPROACH)

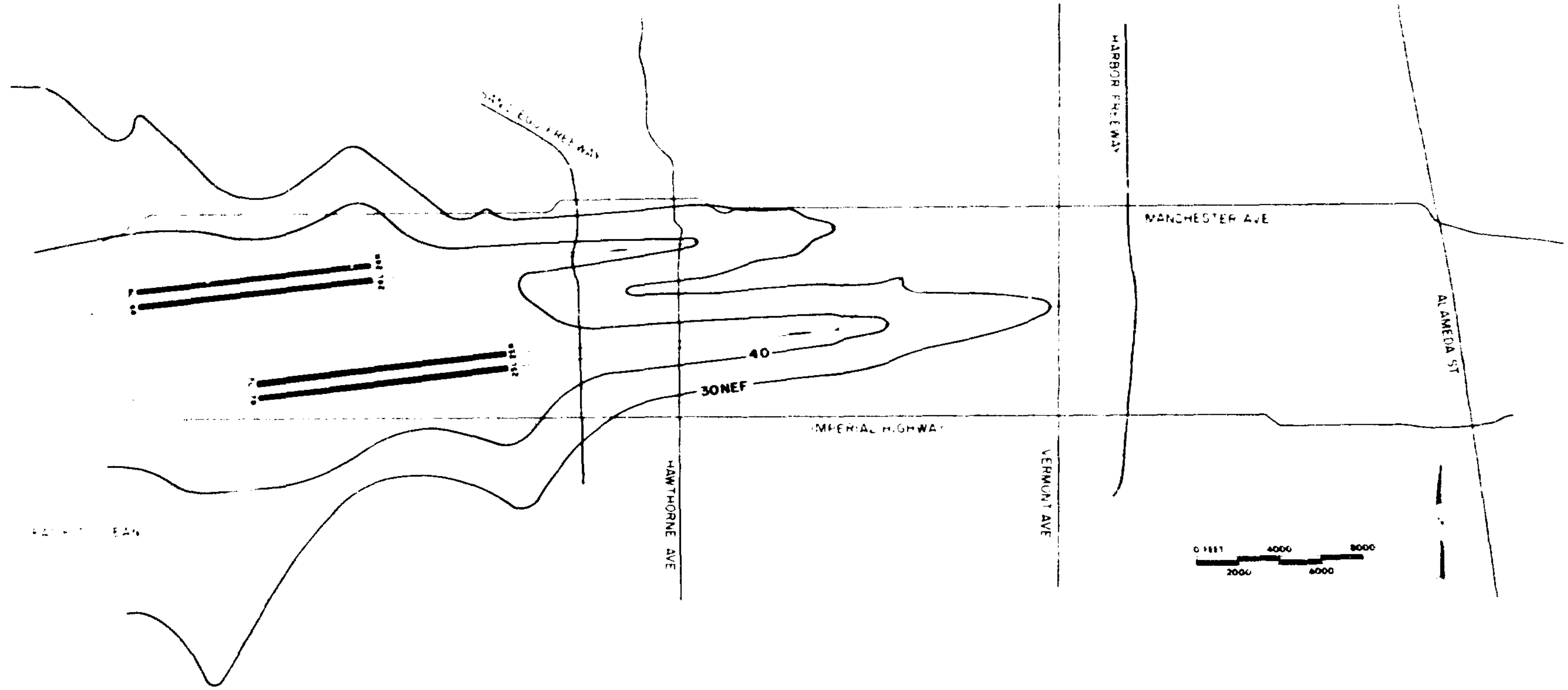


FIGURE 9-C. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT LOS ANGELES INTERNATIONAL AIRPORT - OPERATIONAL CHANGES AND RETROFIT OF FOUR ENGINE TURBOFAN AIRCRAFT WITH LINED NACELLES

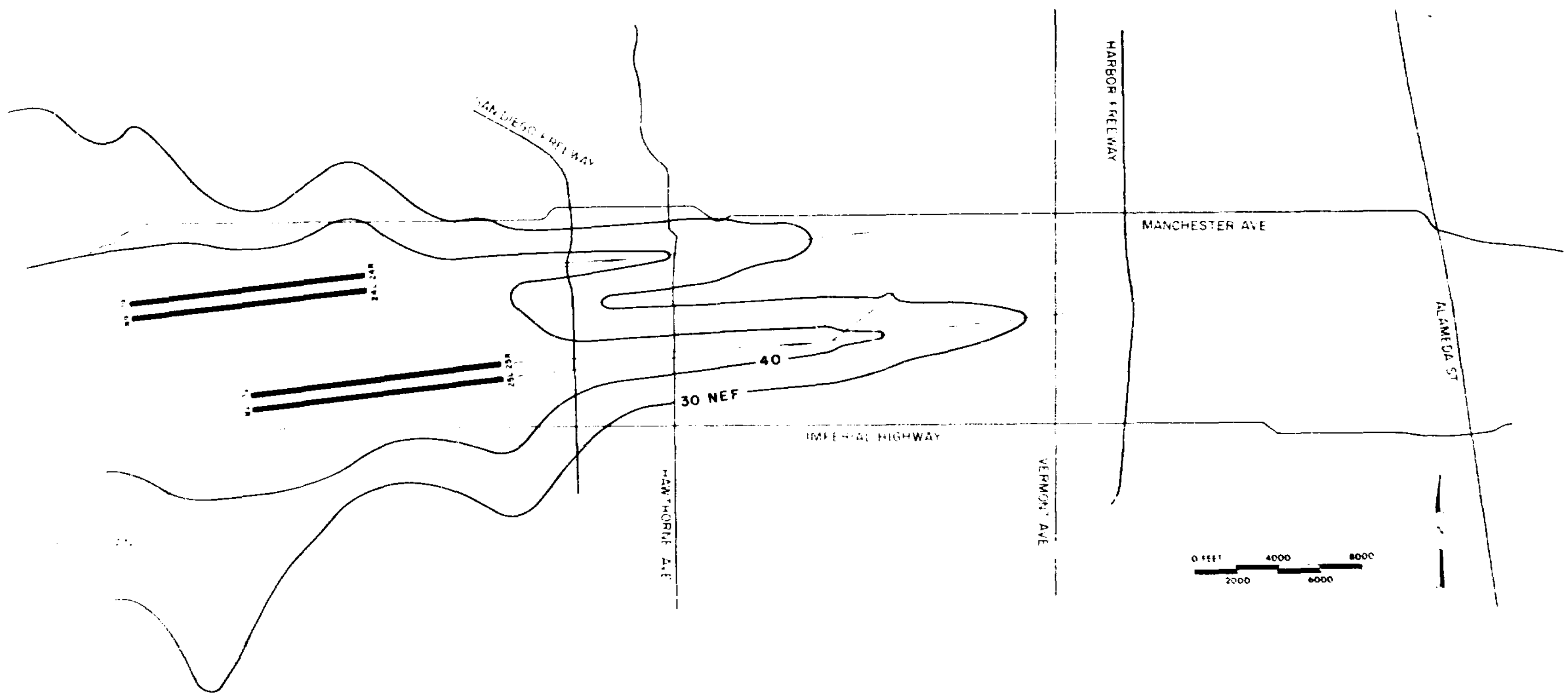


FIGURE 9-D. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT LOS ANGELES INTERNATIONAL AIRPORT - OPERATIONAL CHANGES AND RETROFIT OF FOUR ENGINE TURBOFAN AIRCRAFT WITH A "QUIET" ENGINE

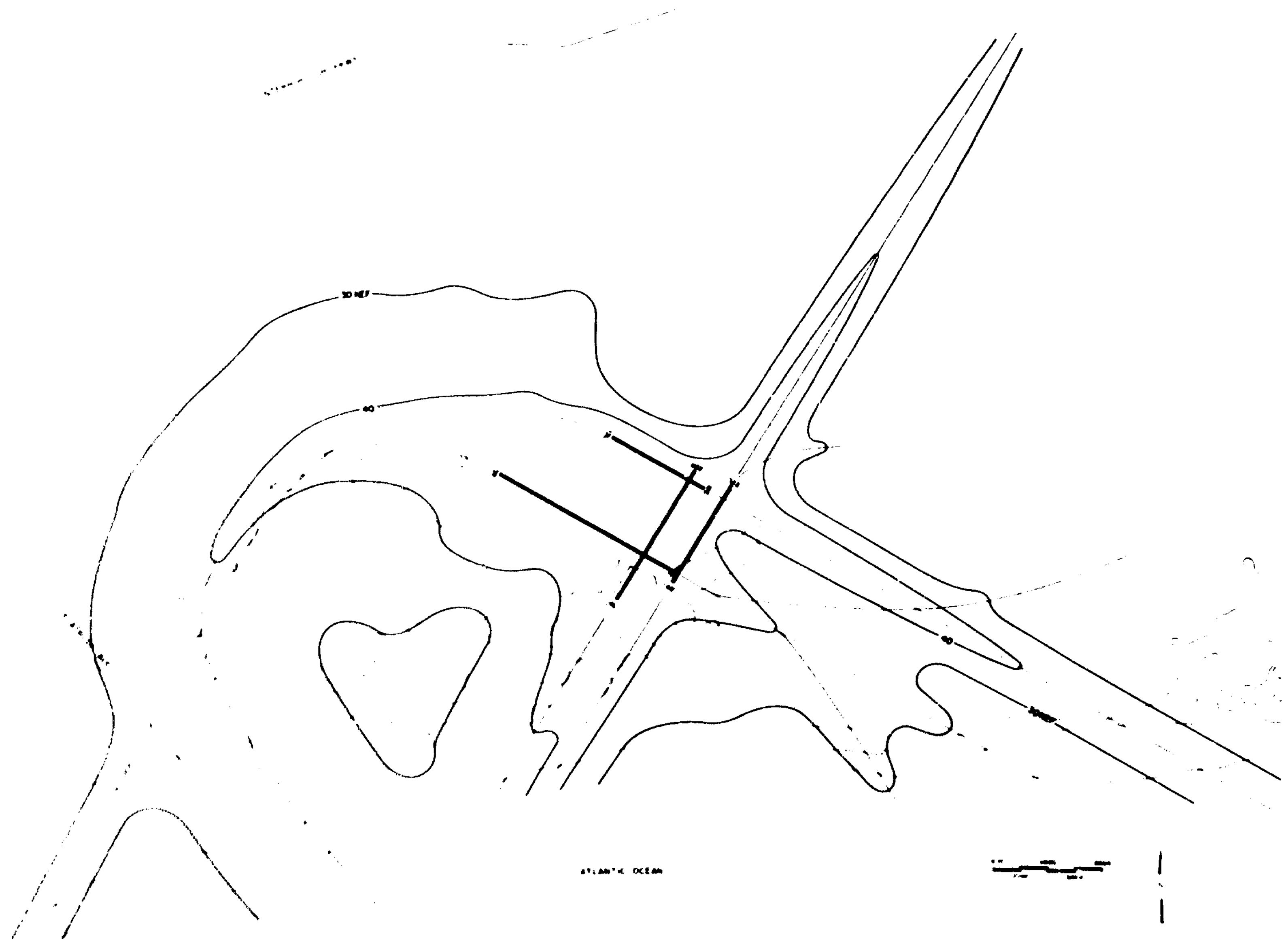


FIGURE 10-A. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT JOHN F. KENNEDY INTERNATIONAL AIRPORT, NEW YORK - "BASELINE" CONDITIONS WITH NO SPECIAL NOISE ABATEMENT CHANGES

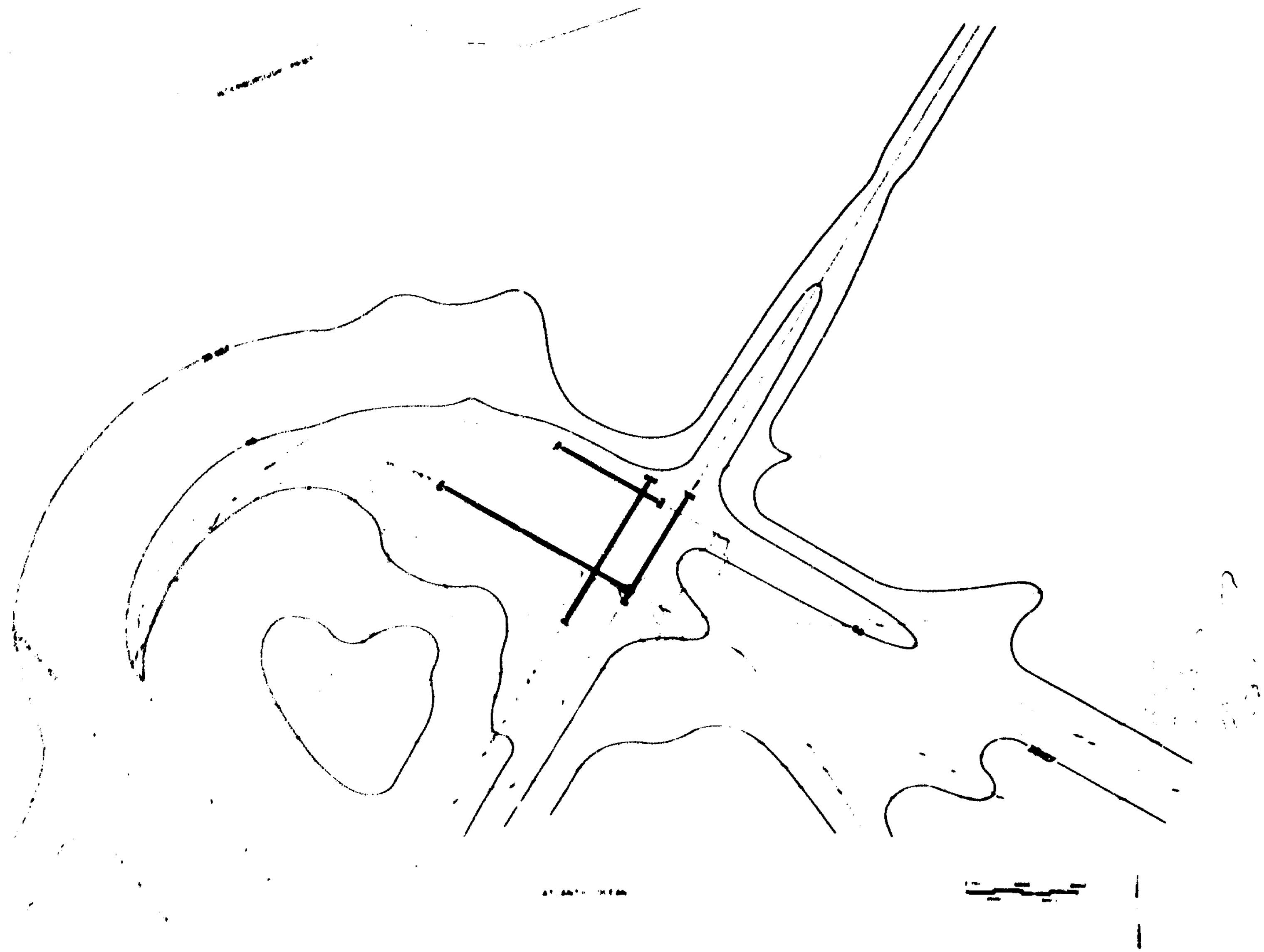


FIGURE 10-8. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT JOHN F. KENNEDY INTERNATIONAL AIRPORT, NEW YORK - OPERATIONAL CHANGES ONLY (THRUST CUTBACK AFTER TAKEOFF AND TWO SEGMENT APPROACH)

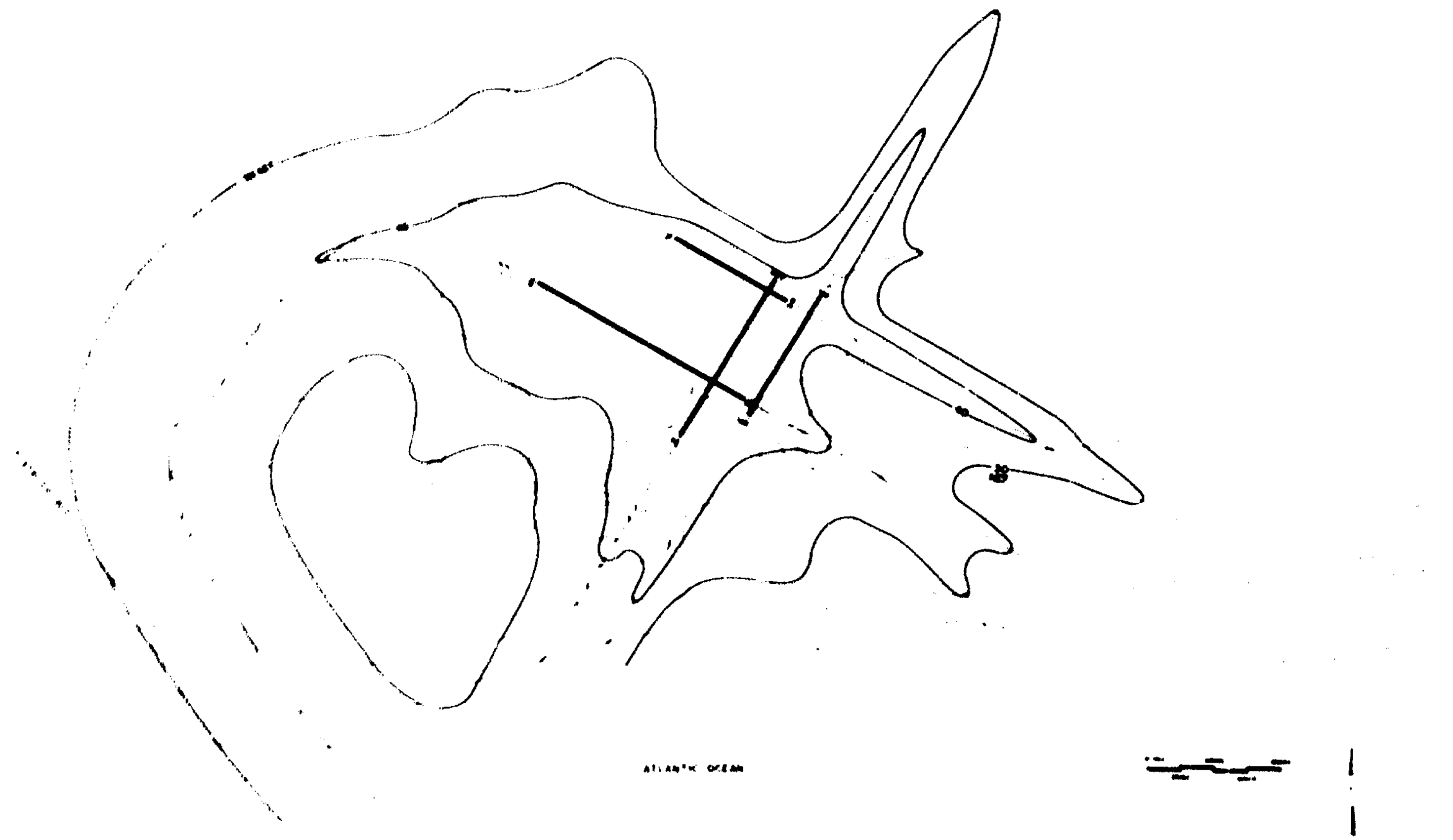


FIGURE 10-C. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT JOHN F. KENNEDY INTERNATIONAL AIRPORT, NEW YORK - OPERATIONAL CHANGES AND RETROFIT OF FOUR ENGINE TURBOFAN AIRCRAFT WITH LINED NACELLES

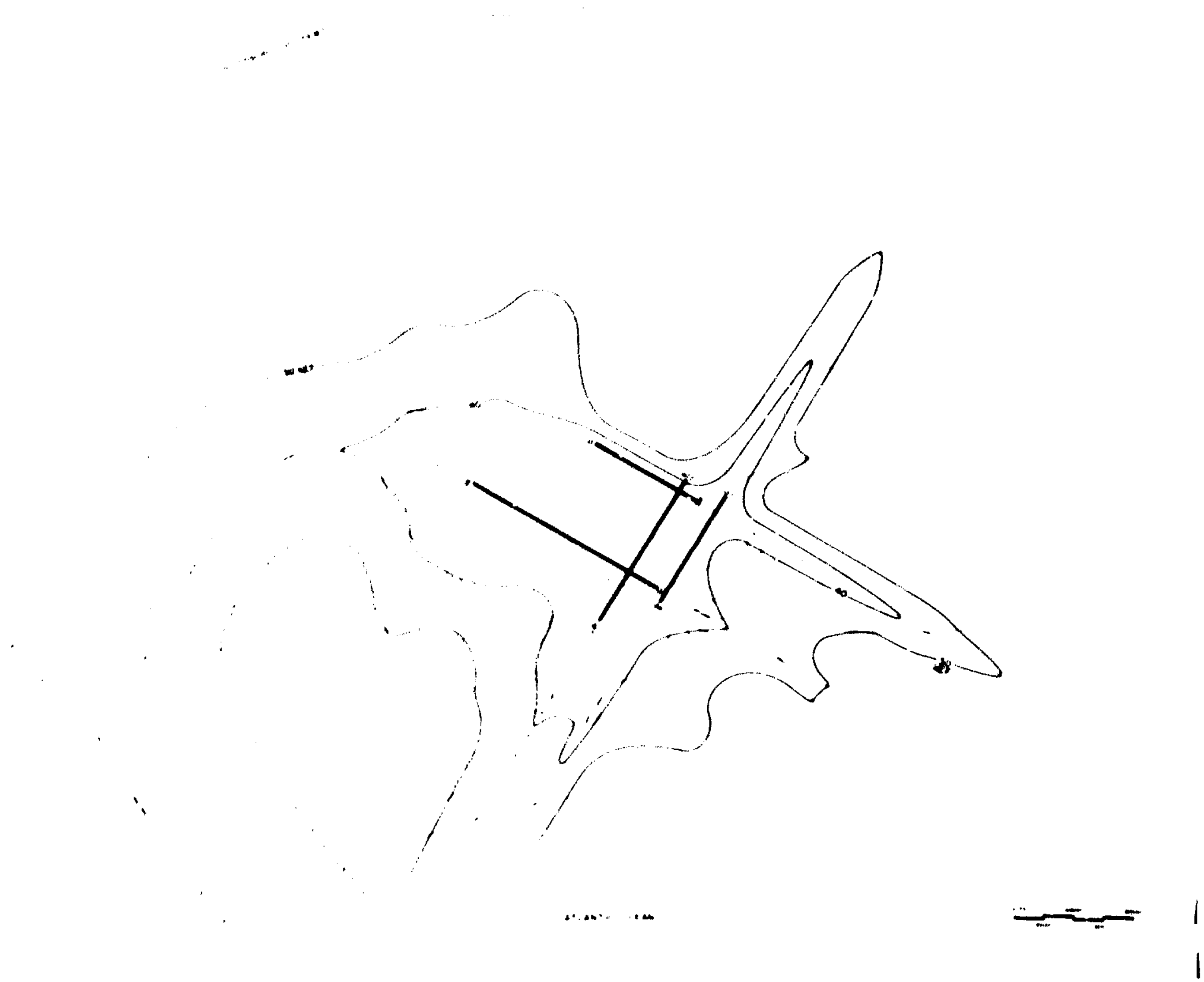


FIGURE 10-D. NOISE EXPOSURE FORECAST CONTOURS FOR 1975 OPERATIONS AT JOHN F. KENNEDY INTERNATIONAL AIRPORT, NEW YORK - OPERATIONAL CHANGES AND RETROFIT OF FOUR ENGINE TURBOFAN AIRCRAFT WITH A "QUIET" ENGINE

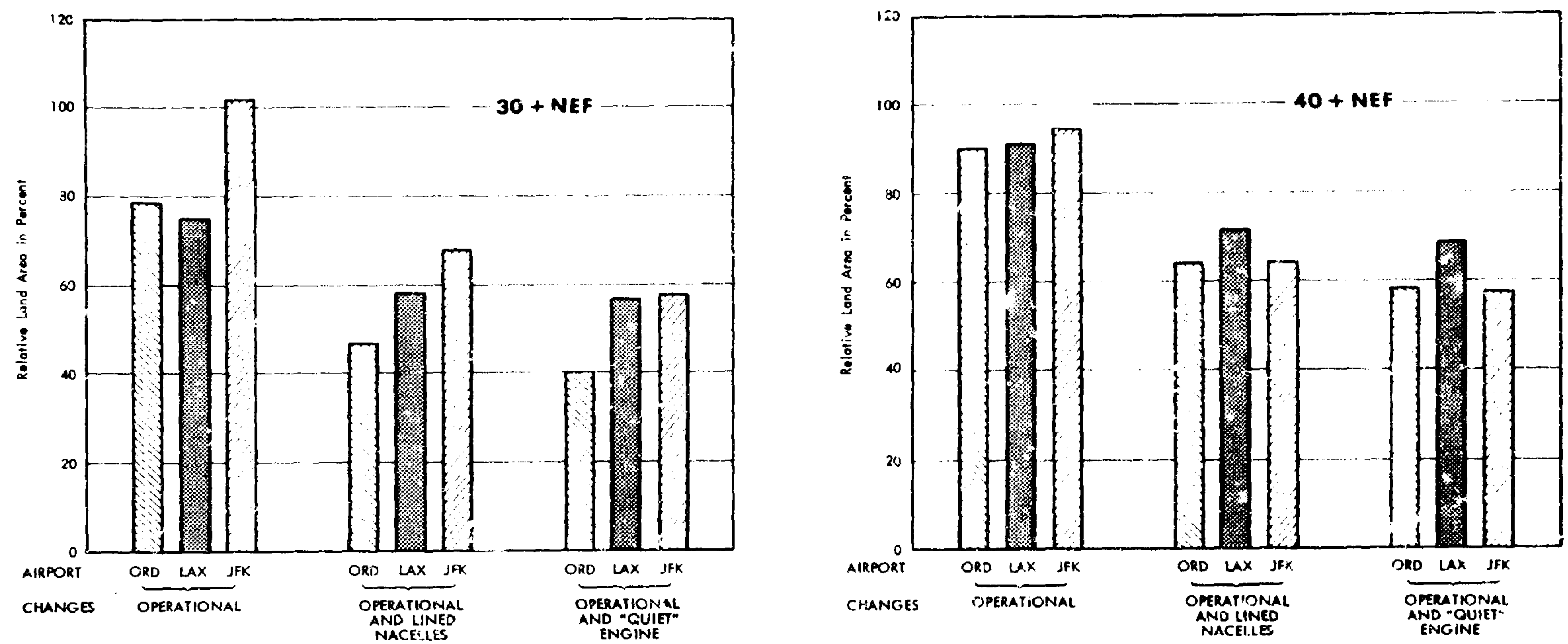


FIGURE 11. RELATIVE LAND AREAS WITHIN NEF 30 AND NEF 40 CONTOURS

APPENDIX A

SUMMARY OF AIRCRAFT NOISE AND PROFILE INFORMATION USED IN NEF COMPUTATIONS

APPENDIX A

SUMMARY OF AIRCRAFT NOISE AND PROFILE INFORMATION USED IN NEF COMPUTATIONS

This appendix summarizes the aircraft noise and takeoff profile information used in the computation of NEF contours. In the computations, aircraft noise and takeoff profiles are specified for 9 major aircraft classes which cover current and projected future commercial jet transport through 1975 and also current multi-engine piston and turboprop aircraft having maximum gross weights over 12,500 lbs.

Table A-1 is a guide to the selection of the appropriate set of effective perceived noise level (EPNL) curves and takeoff profiles for each class of aircraft. The table lists the major aircraft class and examples of aircraft in each class. The table also identifies the appropriate set of EPNL vs. slant distance curves, given in Figs. A-1 through A-8, for each aircraft class. Slant distance is defined as the length of the imaginary straight line passing through the point of interest on the ground and the aircraft flight path which forms the hypotenuse of the vertical right triangle whose legs are normal to the flight track or its tangent.

Several different aircraft are usually included in each aircraft classification. Since these aircraft may differ slightly in both performance and noise characteristics, there may be a spread in noise characteristics for each classification of about ± 3 EPNL.

In Figs. A-1 through A-8, EPNL vs distance curves are given for takeoff power and for typical approach power settings. Several of the EPNL vs distance charts also show an EPNL curve for estimating sideline noise levels during aircraft takeoff. This curve is an estimate of the maximum EPNL which would be observed to the side of the runway at or near the beginning of the takeoff roll. In the NEF computations, EPNL values during the takeoff roll are adjusted to account for the changes in level and duration due to forward speed and acceleration of the aircraft along the runway as the aircraft is taking off. The sideline noise levels will be approximately 5 to 8 EPNdB less than the curves shown at or near the point where the aircraft becomes airborne. After liftoff, the air to ground takeoff EPNL curves are used, resulting in an increase of noise after the aircraft becomes airborne.*

---

* These calculation procedures are discussed more completely in Ref. 10.

Selection of the appropriate takeoff profile is determined by the aircraft class and, for most aircraft classes, the trip length, as listed in Table A-1. The takeoff profiles are shown in Fig. A-9. All landing profiles are based upon a 3 degree glide slope, with the aircraft descending over the runway threshold at a height of 50 feet.

The selection of takeoff profile for a given aircraft class on the basis of trip length assumes a reasonably direct correlation between trip length and operating gross weight. This choice is also based upon the consideration that trip length information is generally obtainable from aircraft forecast data, while percentages of operating gross weights is much less easily obtainable.

With regard to takeoff profile characteristics, it is recognized that more precise profiles can readily be developed for any specific aircraft type when detailed information concerning aircraft gross weight or operation procedures is specified. It is also recognized that, in some cases, trip length is not an accurate guide to selection of takeoff profiles nor to percentage of operating gross weight, particularly when considering aircraft freight operations or short haul flights where refueling does not occur at each stop.

It also should be recognized that maximum aircraft climb out capabilities are often not utilized in routine airline operations. Standarized airline takeoff procedures and limitation of takeoff profiles to deck angles based on passenger comfort considerations act to modify the choice of takeoff profiles over a simple selection based upon either trip length or a percentage of maximum gross weight.

The aircraft noise and profile information given in this Appendix is based upon information from many sources. These sources include:

a. Studies conducted by Bolt Beranek and Newman Inc. (BBN) for the Port of New York Authority, and for airframe manufacturers where extensive positional and acoustical data were obtained during a variety of controlled aircraft operations;

b. Numerous studies conducted by BBN in the vicinity of civil airports where accurate positional and acoustical data were obtained during routine airline takeoff and landing operations but where detailed information concerning aircraft operating conditions (power settings, operating gross weight, etc.) were lacking;

c. Aircraft noise and performance information reported by the FAA and by NASA.

d. Noise and operational characteristics estimates for future aircraft provided by the FAA and recent technical publications, supplemented by BBN studies;

e. Noise and operational characteristics summaries provided by the Aircraft Industries Association Aerospace Technical Council.

As described in Ref. 9, the NEF computation program provides means for the addition of new or modified noise and profile information and for the introduction of special profiles which might be used in studies at specific airports. The current computation program does not include EPNL and takeoff profile information for the following aircraft.

a. Small single and multi-engine propeller aircraft having gross weights of less than 12,500 lbs;

b. Civil or military helicopters;

c. Most military aircraft.

However data concerning these aircraft may be later added to the computational program as the need arises.

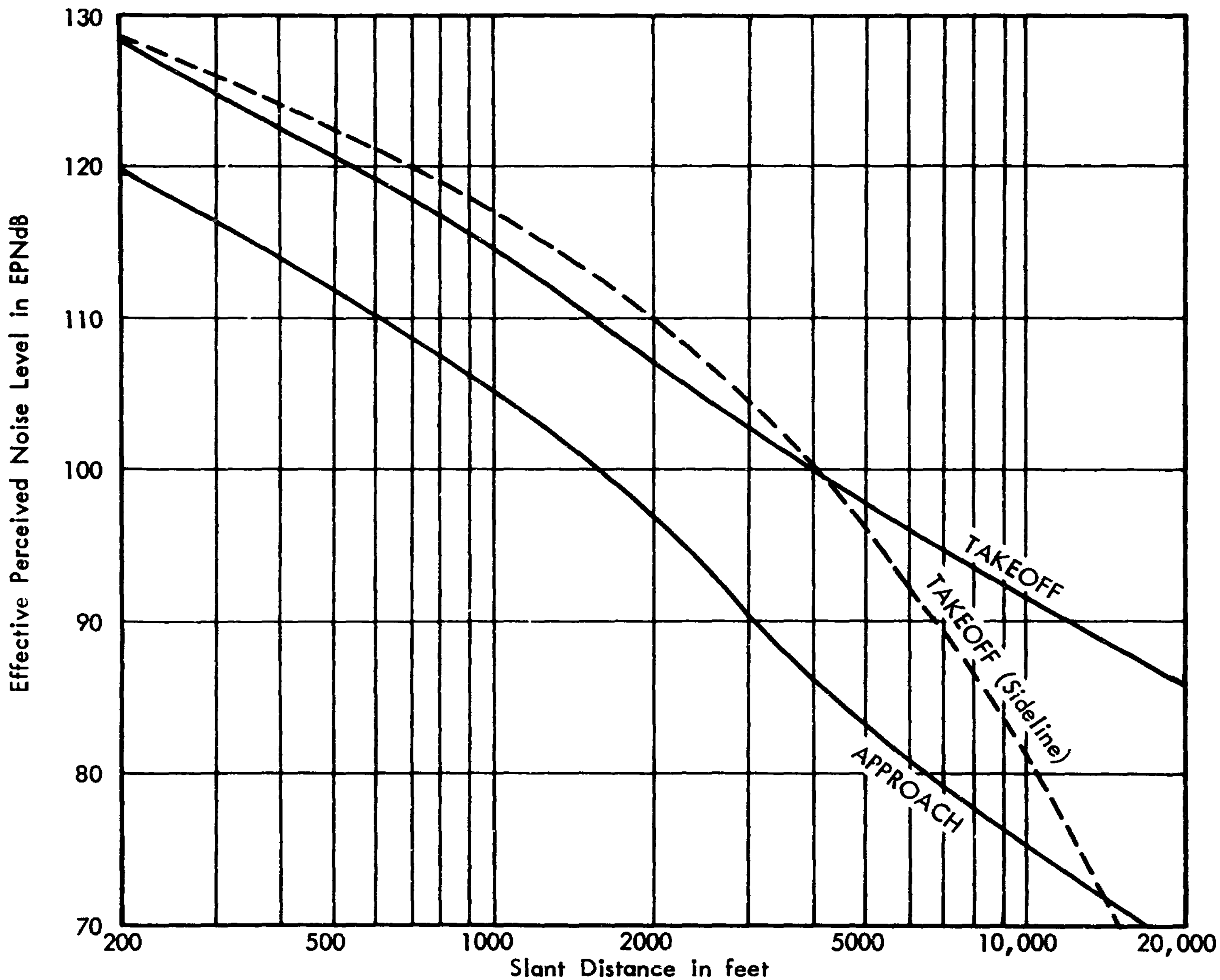


FIGURE A-1. VARIATION IN EFFECTIVE PERCEIVED NOISE LEVELS WITH DISTANCE - FOUR ENGINE TURBOJET TRANSPORT AIRCRAFT

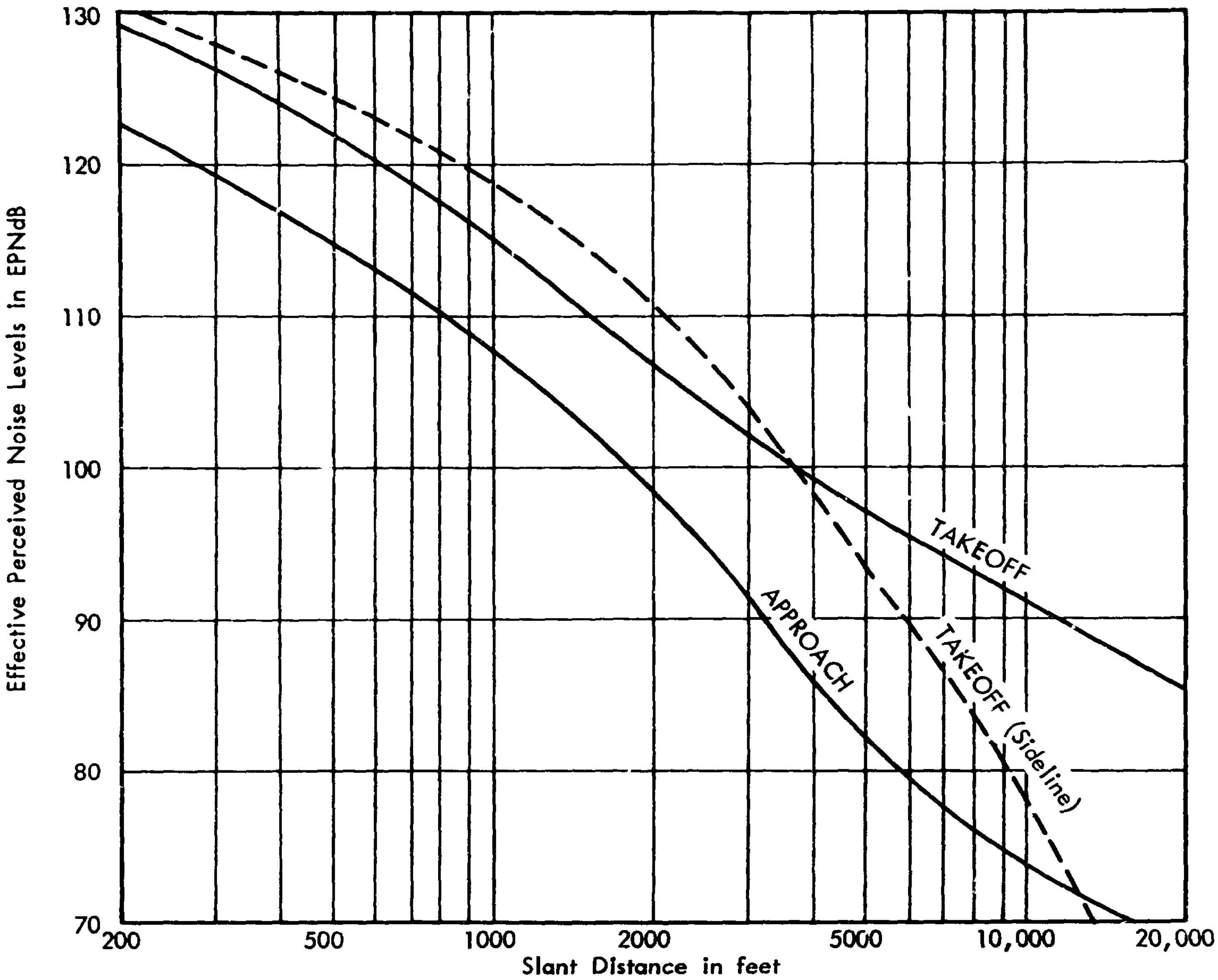


FIGURE A-2. VARIATION IN EFFECTIVE PERCEIVED NOISE LEVELS WITH DISTANCE - FOUR ENGINE TURBOFAN TRANSPORT AIRCRAFT

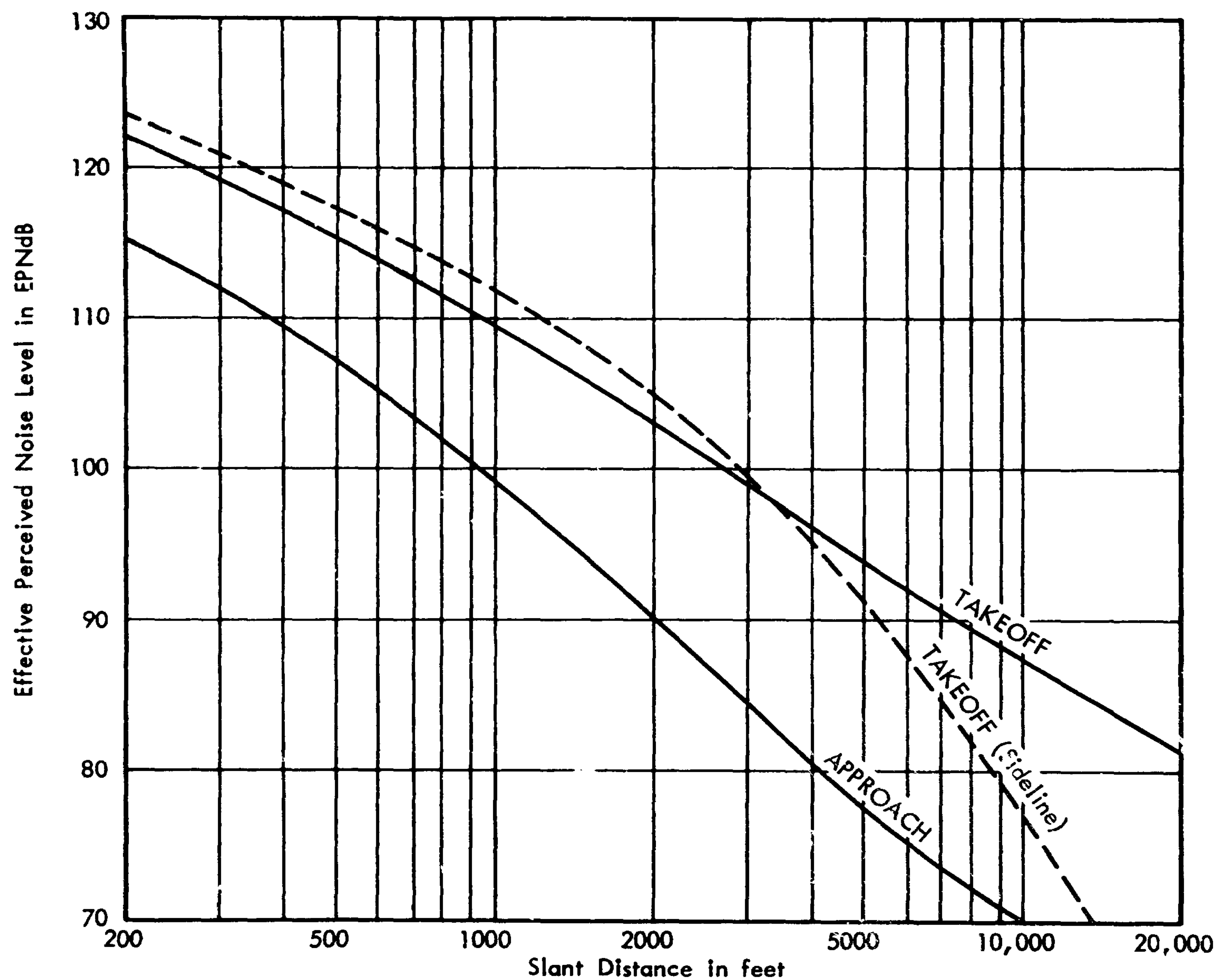


FIGURE A-3. VARIATION IN EFFECTIVE PERCEIVED NOISE LEVELS WITH DISTANCE - TWO AND THREE ENGINE TURBOFAN TRANSPORT AIRCRAFT

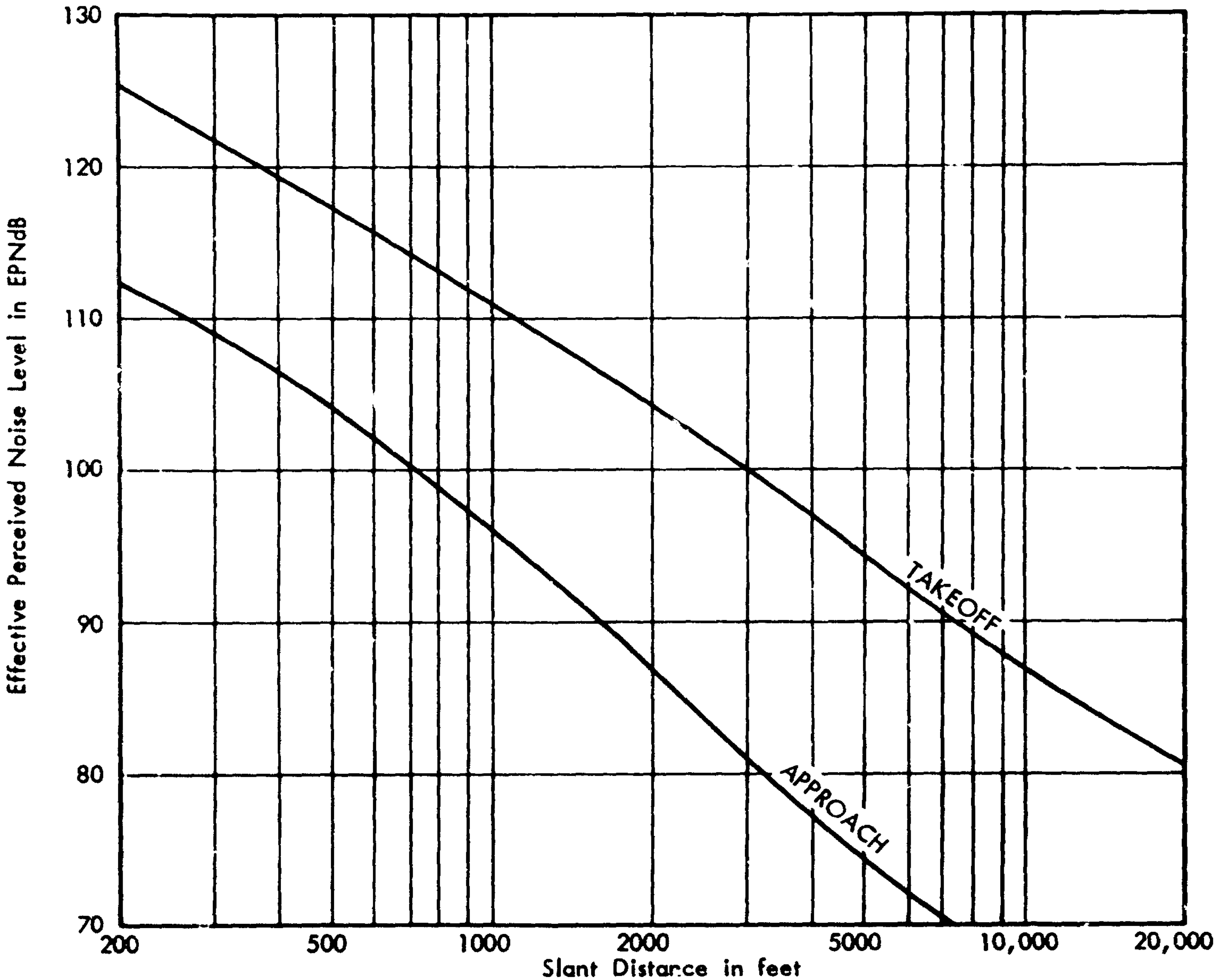


FIGURE A-4. VARIATION IN EFFECTIVE PERCEIVED NOISE LEVELS WITH DISTANCE - "NEW TECHNOLOGY" LARGE FOUR ENGINE TURBOFAN TRANSPORT AIRCRAFT

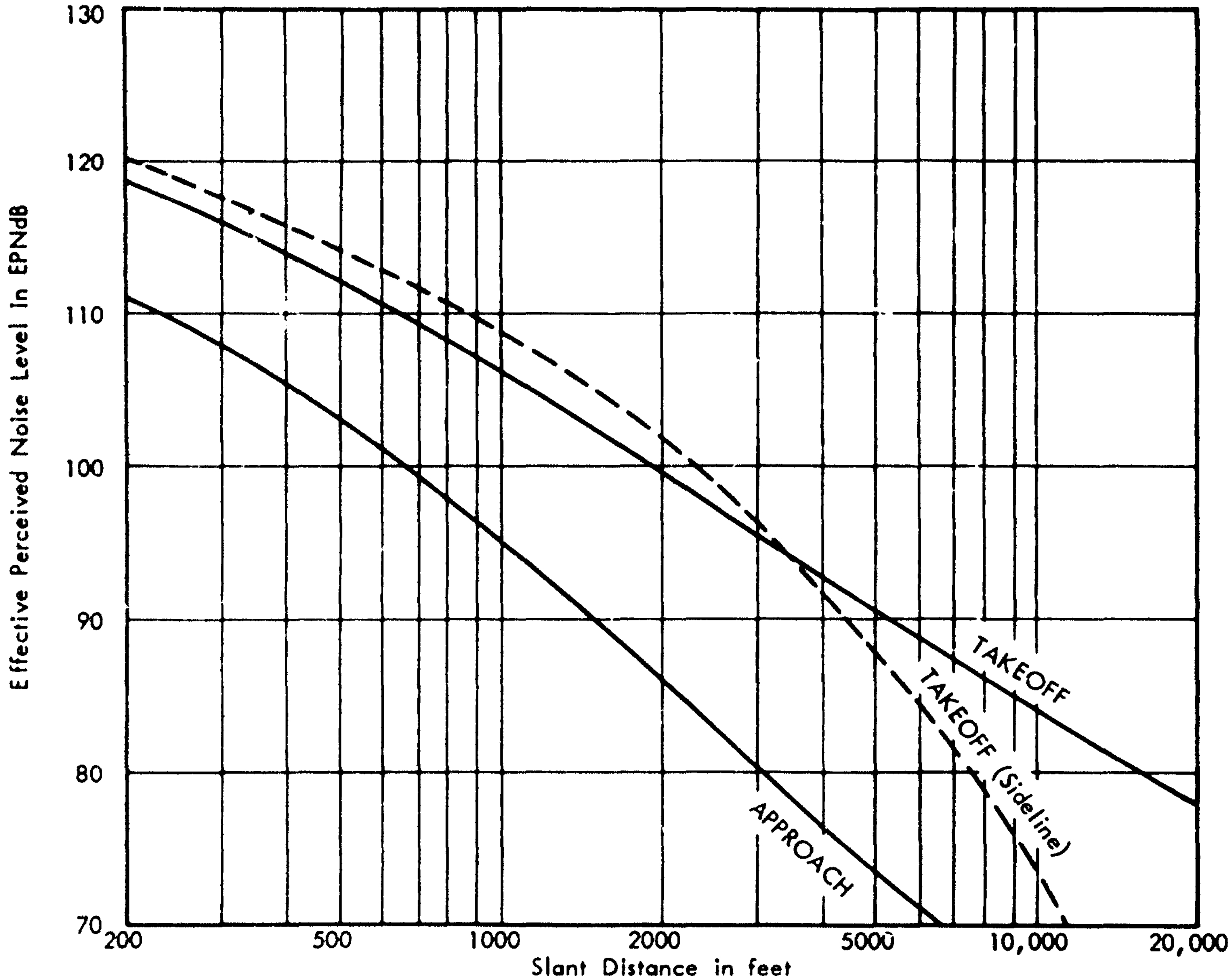


FIGURE A-5. VARIATION IN EFFECTIVE PERCEIVED NOISE LEVELS WITH DISTANCE - "NEW TECHNOLOGY" LARGE THREE ENGINE TURBOFAN TRANSPORT AIRCRAFT

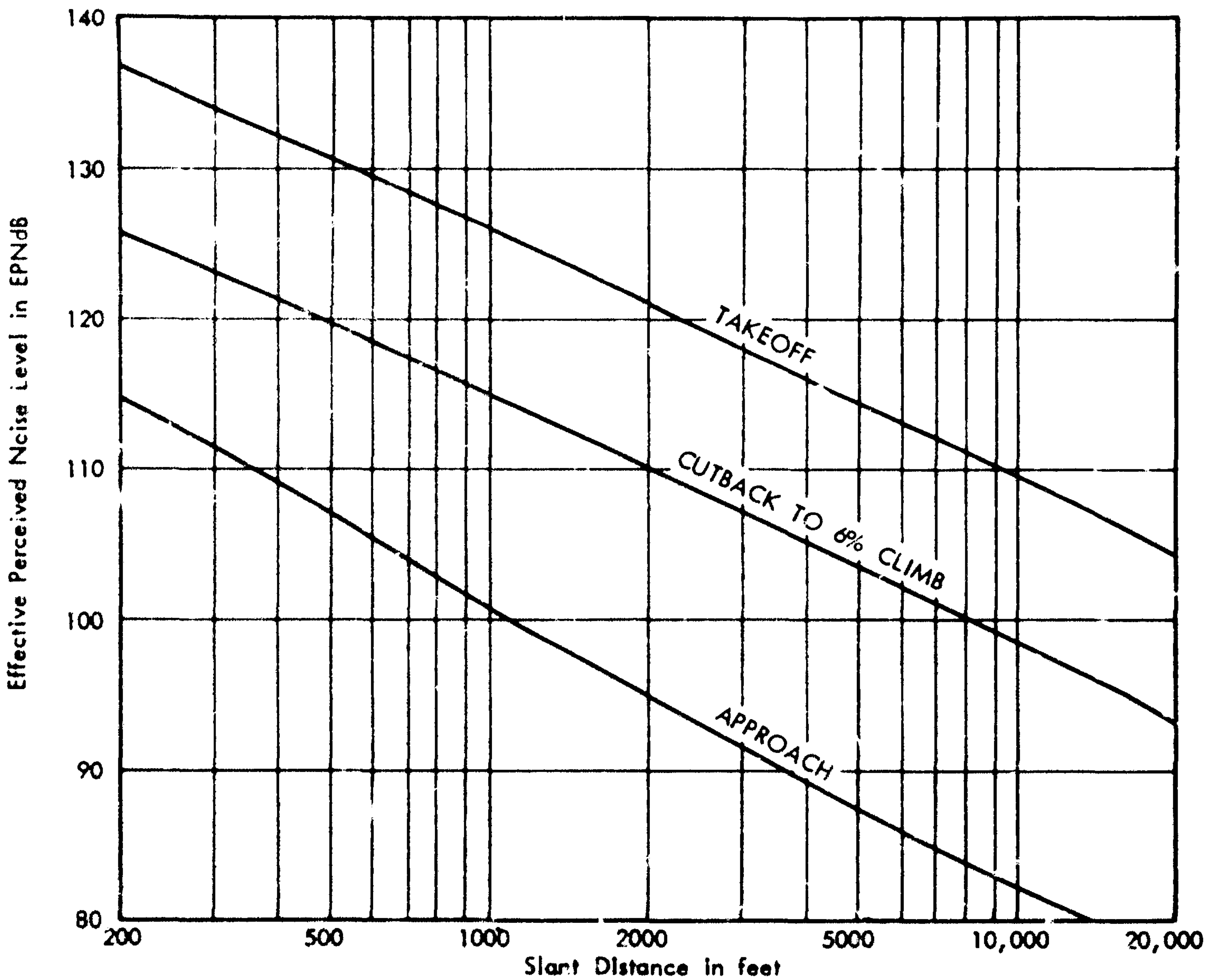


FIGURE A-6. VARIATION IN EFFECTIVE PERCEIVED NOISE LEVELS WITH DISTANCE - U.S. SUPERSONIC TRANSPORT AIRCRAFT

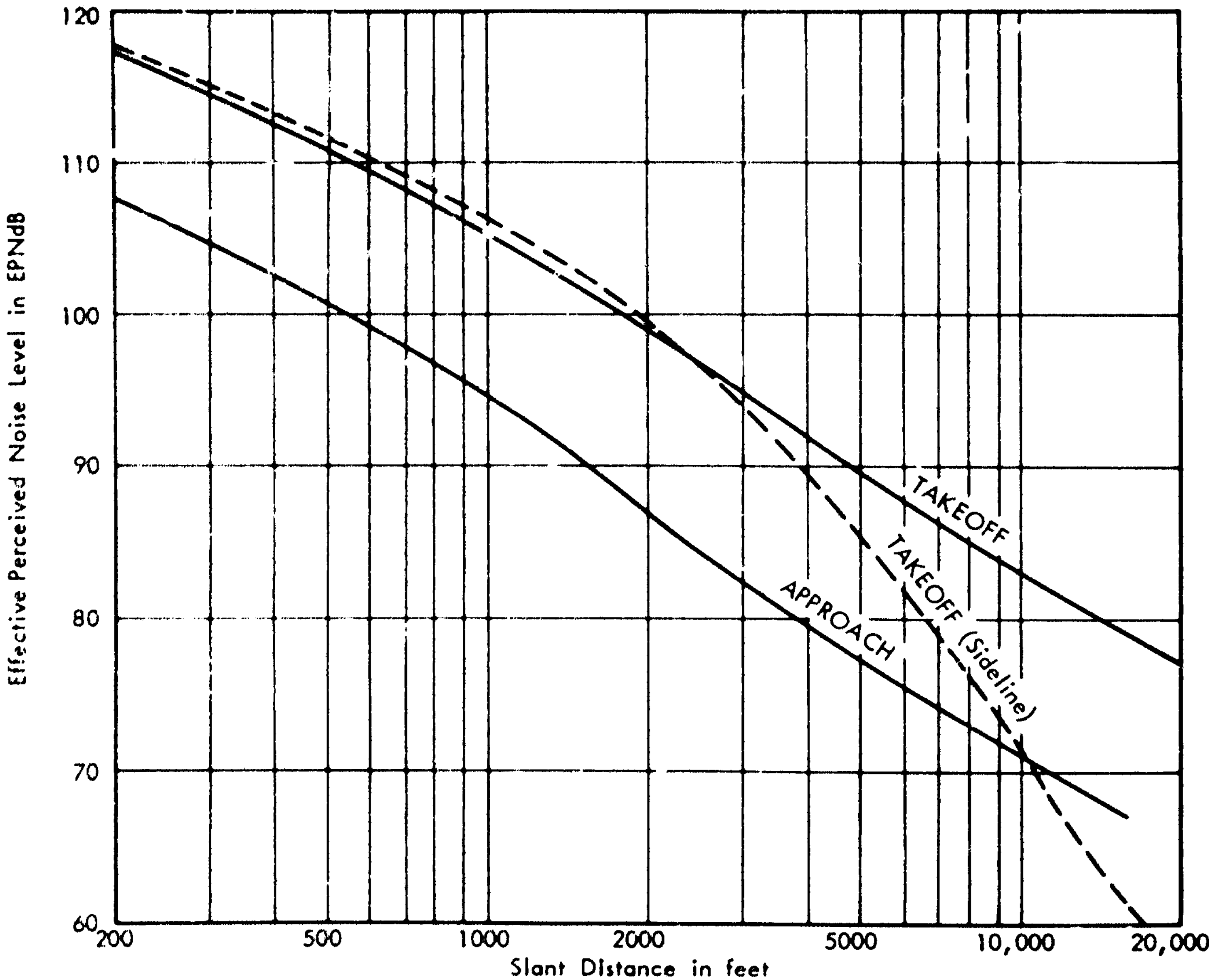


FIGURE A-7. VARIATION IN EFFECTIVE PERCEIVED NOISE LEVELS WITH DISTANCE - TWO ENGINE BUSINESS TURBOJET AIRCRAFT

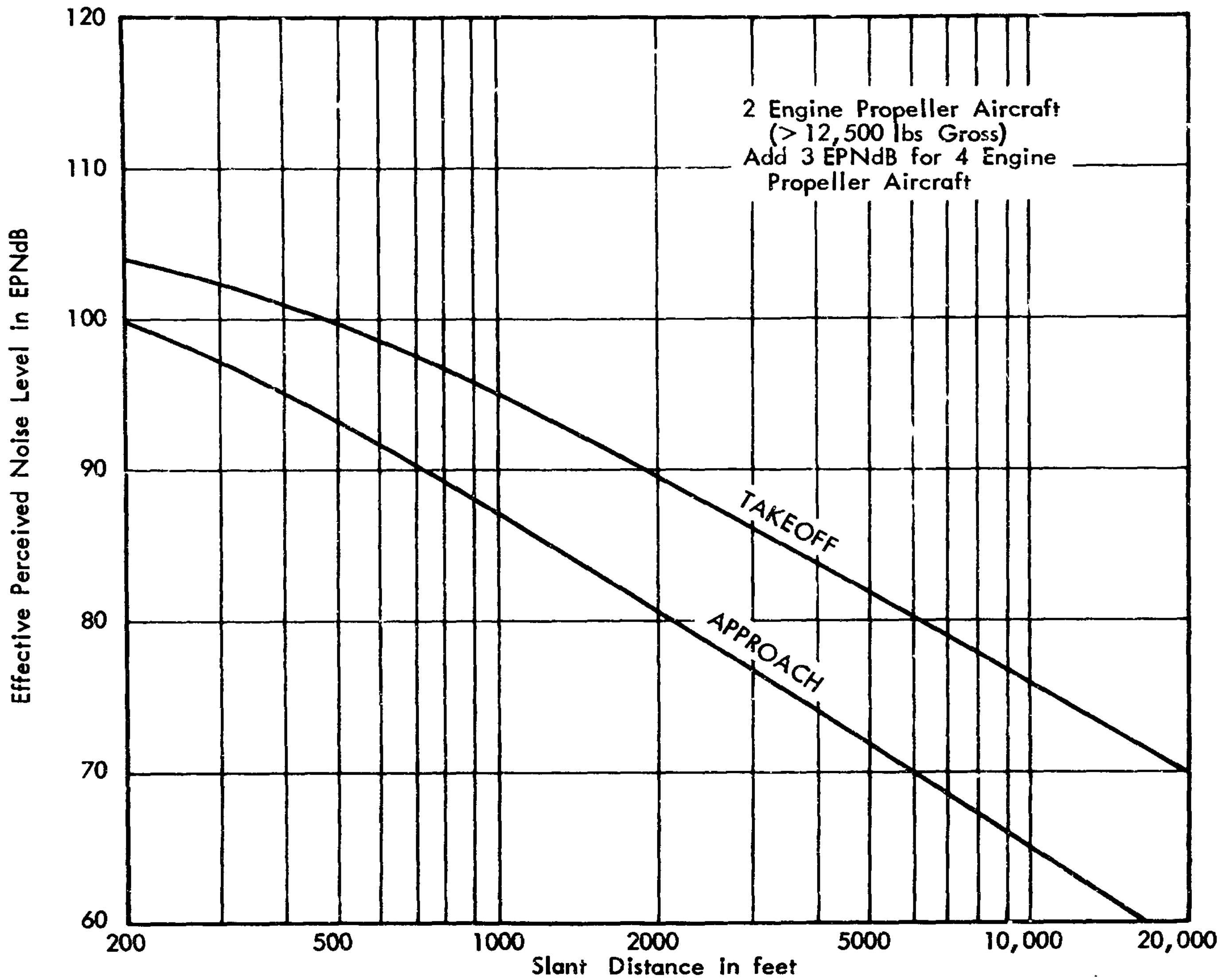


FIGURE A-8. VARIATION IN EFFECTIVE PERCEIVED NOISE LEVELS WITH DISTANCE - TWO AND FOUR ENGINE PROPELLER AIRCRAFT
(Gross Weight Greater Than 12,500 lbs)

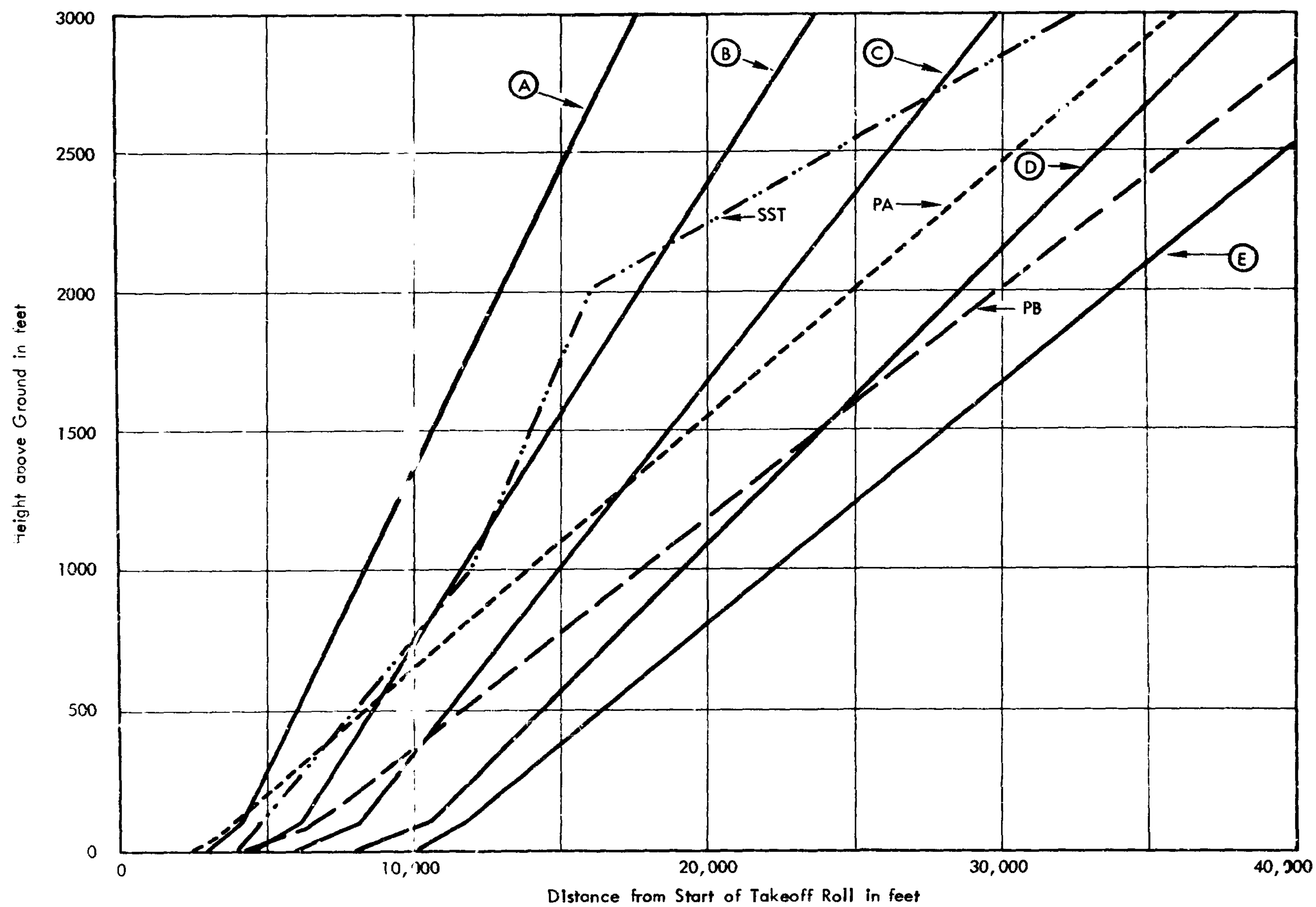


FIGURE A-9. GENERALIZED TAKEOFF PROFILES

APPENDIX B

SUMMARY OF BASIC NOISE EXPOSURE FORECAST EQUATIONS

APPENDIX B

SUMMARY OF BASIC NOISE EXPOSURE FORECAST EQUATIONS

In calculation of NEF values, aircraft noise levels are expressed in terms of the effective perceived noise level (EPNL) as defined in Ref. 11. In estimating the noise exposure near an airport or flight path resulting from the operation of a number of different aircraft, it is convenient to group the aircraft in classes based upon consideration of the aircraft noise characteristics and takeoff and landing performance. Each class is assigned a description of the noise in terms of a set of EPNL vs. distance curves and a set of takeoff and landing profiles. Thus, for a given class of aircraft at a particular power setting (i.e. takeoff power) it is assumed that the aircraft noise characteristics may be described by a single EPNL vs. distance curve.

The total noise exposure produced by aircraft operations at a given point is viewed as being composed of the effective perceived noise levels produced by different aircraft classes flying along different flight paths. For aircraft class i on flight path j, the NEF (ij) can be expressed as

$$NEF\ (ij) = EPNL\ (ij) + 10 \log \left[\frac{N\ (day)\ (ij)}{K\ (day)} + \frac{N\ (night)\ (ij)}{K\ (night)}\right] - C \qquad \text{(Eq. 1)}$$

where

NEF (ij) = Noise Exposure Forecast value produced by aircraft class (i) along flight path segment (j).

EPNL (ij) = Effective perceived noise level produced at the given point by aircraft class (i) flying along flight path segment (j).

K - Constant normalizing the adjustment in NEF values due to volume of operations. Different values of K are used for daytime and nighttime movements.

C = Arbitrary normalization constant.

K (day) is chosen so that for 20 movements of a given aircraft per daytime period, the adjustment for number of operations is zero. Hence,

$$10 \log \frac{20}{K\,(\text{day})} = 0; \; K(\text{day}) = 20$$

K (night) is chosen such that for the same average number of operations per hour during daytime or nighttime periods the NEF value for nighttime operations would be 10 units higher than for daytime operation. Hence,

$$10 = 10 \log \left(\frac{K\,(\text{day})}{K\,(\text{night})} \right) \cdot \frac{9}{15}$$

where 9 and 15 are the number of hours in the nighttime and daytime periods respectively.

And, K (night) = 1.2

The value assigned to C is 75. Choice of this value is based upon two considerations. First, it is desirable that the number assigned to the NEF values be distinctly different in magnitude from the effective perceived noise level so that there is little likelihood of confusing effective perceived noise levels with NEF values. A second aspect is the desirability of selecting a normalization factor that will roughly indicate the size of the NEF value above some threshold value, indicating the emergence of the noise exposure from levels which would have little or no influence on most types of land usage.

With the above choices for values of K and C, Eq. (1) becomes:

$$\text{NEF}\,(ij) = \text{EPNL}\,(ij) + 10 \log \left[N\,(\text{day})\,(ij) + 16.67\, N\,(\text{night})\,(ij) \right] - 88 \qquad \text{(Eq. 2)}$$

The total NEF at the given ground position may be determined by summation of all the individual NEF (ij) values on an "energy" basis:

$$\text{NEF} = 10 \log \sum_i \sum_j \text{antilog} \frac{\text{NEF}\,(ij)}{10} \qquad \text{(Eq. 3)}$$